For Editorial Contents see page 415

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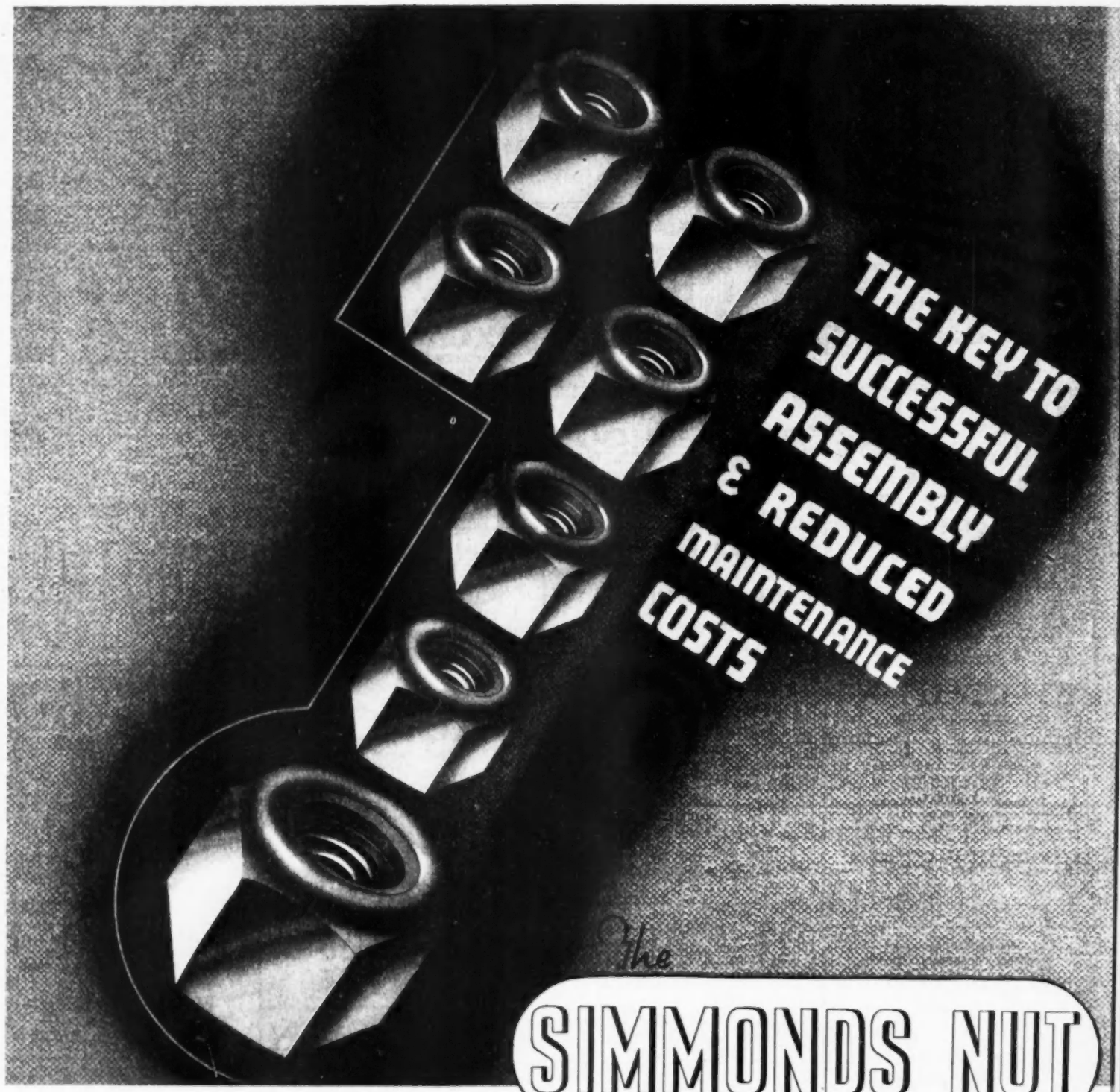

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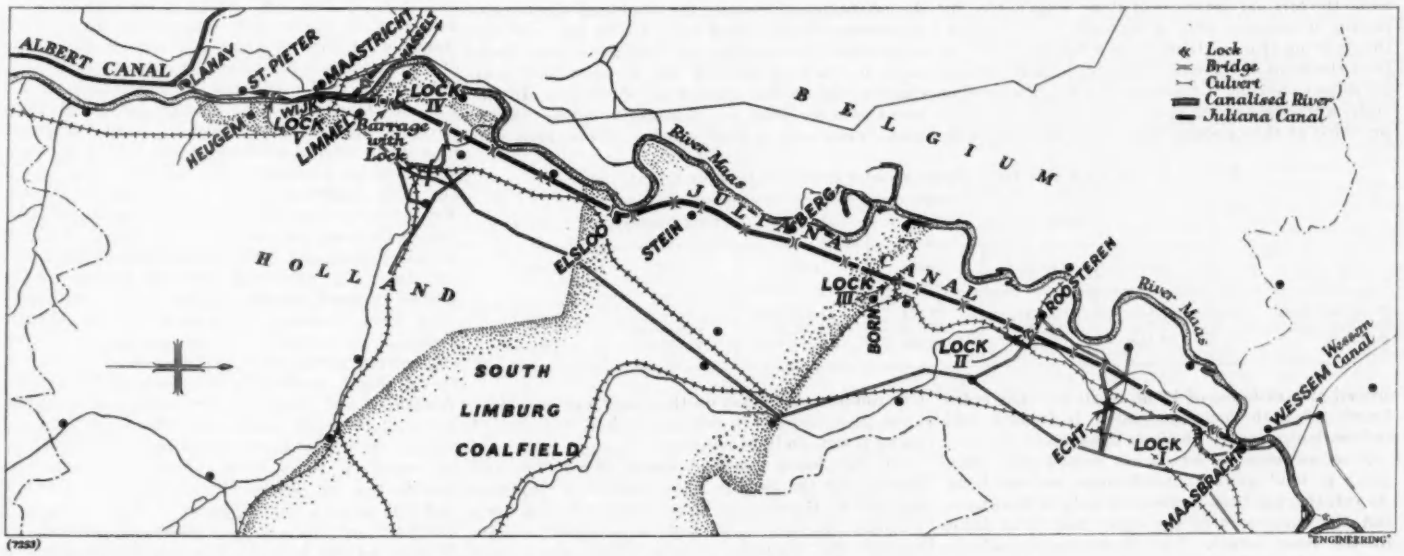
THE JULIANA SHIP CANAL, HOLLAND.

In our series of articles on the Albert Canal,* linking the River Meuse at Liége with the River Scheldt at Antwerp, we had occasion to refer to the Juliana ship canal, constructed by the Dutch Government along the right bank of the River Maas (Meuse) from the town of Maastricht to the village of Maasbracht. In addition to serving the Dutch South Limburg colliery and industrial district, this waterway was originally also intended to attract the shipping of the Belgian Meuse district to the Dutch seaports of Rotterdam and Dordrecht. The decision of the Belgian Government to build the Albert Canal, thereby providing a rapid and adequate means of transit by water from the Liége industrial basin to the sea, has undoubtedly unfavourably affected the volume of traffic on the Juliana Canal. The information given below concerning the operation of the canal and the traffic returns, for which we are indebted to an article appearing in the issue of February 9, 1940, of our Dutch contemporary, *De Ingenieur*, and which was contributed by Mr. C. F. Egelie, the Chief Engineer of the Department of Public Works and the manager of the Juliana Canal, shows that in spite of the new competition, the canal is still playing an important part in the economy of Holland. It ranks third among Dutch ship canals from the point of view of traffic density.

For the better understanding of the traffic data given by Mr. Egelie, it will be desirable to give a brief description of the main features of the Juliana Canal. From the map reproduced on this page, it will be seen that the whole canal scheme comprises the canal proper between Maastricht and Maasbracht, having a length of 34 km.; the canalisation of the River Maas at Maastricht; and a short junction canal, 4 km. long, connecting the latter with the Albert Canal at Lanay. The canal itself is dimensioned to accommodate craft up to 2,000 tons, with a maximum length of 100 m., a breadth of 12 m., a draught of 2·8 m., and a maximum height above water level of 7 m. The junction canal to the Albert Canal cannot as yet accommodate ships of above 1,000 tons and having dimensions exceeding the following: maximum length, 80 m.; breadth, 10·5 m.; draught, 2·5 m.; and height above water level, 5 m. As soon as the traffic conditions warrant it, this junction canal will be enlarged to accommodate ships of 2,000 tons.

The Juliana Canal is divided into three reaches by four locks. The lower, most northerly, reach, approximately 8 km. in length, is separated from the canalised Maas at Maasbracht, which has a retained water level of 20·4 m. above sea level (New Amsterdam gauge) by Lock I, situated at the canal outlet. Normally, this lock deals with a fall of 7·45 m., so that the water level of this reach is kept at 27·85 m. The middle reach, 6·5 km. long, of which the level is kept at 32·65 m., is connected at Roosteren to the lower reach by means of Lock II, having a fall of 4·8 m., and to the upper, southern, reach by Lock III at Born, having a fall of 11·35 m. Normally standing in free communication with the canalised Maas at Maastricht, the water level of this upper reach corresponds with that of the retained level of the Maas at this point, *i.e.*, 44 m. Near the canal intake an emergency flood Lock IV has been built to operate on those rare occasions when, during periods of floods, the water level of the Maas exceeds 44 m. Lock V, situated in the junction canal between the canalised Maas and the Albert Canal, is built for a normal fall of 2·7 m.

The lower reaches of the canal, from Maasbracht to the coaling harbour at Born, were opened to navigation in the spring of the year 1934. Approximately a year later, the section Born to the coaling harbour of Stein followed suit, and in September of the same year (1935) the entire canal, from Maasbracht to Maastricht, was put into service.



The total number of ships, and their total tonnage, passed through the locks at Maasbracht, Roosteren and Born during the years 1936, 1937 and 1938, is given in Table I, on page 404.

An analysis of the traffic passing through the Maasbracht lock, and dividing it into local traffic, between harbours on the canal and through traffic, shows that, on a basis of ship tonnage, the local traffic, in the year 1938, accounted for three-quarters of the total. Of the remaining quarter, one-third was destined for, or originated from, Maastricht, and the remaining two-thirds was traffic to or from Belgium or France. Classified on a basis of nationality, three-quarters of the traffic was of Dutch origin or bound for a Dutch destination; one fifth was destined for or originated on the Rhine; and one-twentieth came from or was bound for other districts.

Combining the above figures with an average canal transportation distance of 20 km., the total annual ton-kilometres reaches the approximate figure of 370,000,000. To this has to be added the total transport of coal from the coaling harbours in a southerly direction to Maastricht, Belgium and France, roughly calculated as being 25,000,000 ton-kilometres. The annual operation and maintenance costs of the canal, including administration, amount to 190,000 Dutch florins (25,333*l.* sterling, at the present exchange of 7·5 florins to the pound), corresponding to a cost per ton-kilometre of 0·05 cent. Dutch, or approximately 0·0275*d.* per ton-mile. These figures compare very favourably with the navigation tax levied in Belgium, amounting to 0·015 franc or 0·1 cent Dutch (0·053*d.* per ton-mile), which will be increased to 0·02 Belgian franc or 0·13 cent Dutch (0·069*d.* per ton-mile) as soon as the Albert Canal is in full commission.

As the total quantity of goods locked through at Maasbracht in 1938 amounted to 7,524,000 tons, the cargo load percentage of the ship tonnage of 15,495,000 was, therefore, 48·6 per cent. The average cargo load percentage of North-bound traffic was 84·5 per cent., as compared with 9·8 per cent. for the goods shipped to the south. The bulk of the shipments were coal and coke, reaching a figure of 4,732,000 metric tons. Other figures were sand and gravel, 621,000 tons; natural stone, 561,000 tons; cement and lime, 439,000 tons; artificial manure, 396,000 tons; and iron and steel, 275,000 tons. Of the ships passed through the Canal, 87 per cent. bore the Dutch flag, 9 per cent. the Belgian flag, the rest being of German, French, Swiss, British or Luxemburg nationality.

For inter-harbour traffic the mean tonnage of the ships using the Canal during 1938 was 445. Omitting tugs, this figure is increased to 605 tons, while for through traffic the corresponding figure is 250 tons. Data regarding the dimensions of the various craft were collected at Roosteren during a period of one month at the end of the year 1936. The overall length and width of 2,191 vessels were measured. Of the special types or craft, the so-called Kempenaar, measuring 50 m. by 6·60 m., preponderated. Of this type, 437 used the Juliana Canal, corresponding to 20 per cent. of the total. There were 727 vessels larger than the Kempenaars, of which 155 belonged to the Rhine-Herne Canal type (80 m. by 9·50 m.), and 85 were Dortmund Ems Canal craft (67 m. by 8·20 m.). There were also 224 vessels larger than the Rhine-Herne Canal type, or 10 per cent. of the total. The boats smaller than the Kempenaar, 1,027 in number, were of no special type. The so-called Spits class (38 m. by 5 m.) was represented by 77 craft; the Sambre barge (47 m. by 5 m.) by 63, and the Frisian ship (31 m. by 5·40 m.) by a still smaller number.

On the Juliana canal the locks are operated from 4 a.m. to 10 p.m. on weekdays and from 4 a.m. to noon on Sundays. For the 42,074 ships locked through at Maasbracht in the year 1938, 8,480 lockings were necessary. From December 20 to 29 navigation was impossible owing to ice; hence locking took place during 355 days. The average number of lockings per day amounted to 23·9. The average number of ships occupying the locks simultaneously was 4·1, with a cargo capacity of 1,827 tons. The average locking time per day, including stops in between, amounted to 15 hours 21 minutes. The average duration of one locking works out to 38·5 minutes. For the locking proper, *i.e.*, the shutting and opening of the gates, and the filling or emptying of the lock chamber, only 10·5 minutes were necessary. Comparing the results of 1939 with those of 1936, shows that a larger number of ships could be handled by increasing the number of ships per locking and by increasing the number of lockings per day. Notwithstanding the increase of the number of ships, the average time for entering or leaving the locks was maintained. This result was due to the special measures taken to limit the

* See ENGINEERING, vol. 148, pages 375, 431, 489, 574, and 657 (1939).

duration of locking, while the proportionate increase in the number of self-propelled vessels tended towards the same result.

The question whether the relatively small locks will be able to cope with the future denser traffic may be answered in the affirmative. By regulating the traffic and introducing the measures discussed below, the shipping time rate could be appreciably accelerated. Observations show that under normal conditions it is the rule that vessels arriving at Maasbracht before 1 p.m. can cover the distance of the 13-km. long canal section, Maasbracht-Born, including the passing through the three locks, in 5 to 6 hours. For vessels arriving at Maasbracht after 4 p.m., the time taken will be 13 to 16 hours, on account of the shut-down at night. Since the canal has been in active service, many measures have been introduced to regulate the traffic and to carry out the locking in and out operations in an orderly manner. Mooring space is of primary importance. Originally, seven mooring piles placed 30 m. to 40 m. apart, were provided at both the top and bottom of each lock. As this arrangement proved inadequate, the mooring space was increased by placing 12 mooring piles at distances of 25 m., while the original distances of 40 m. were halved by placing a mooring pile in between. At present, the mooring space extends over a length of 650 m. from the front of the lock and is principally utilised by ships exceeding a tonnage of 400. For smaller craft, a mooring space about 250 m. long has been provided at the opposite bank, with mooring posts spaced at a distance of 15 m. to 20 m. The entire length of both mooring spaces is lighted with sodium lamps spaced at 50 m. distance.

A second measure which has proved very efficacious is loud-speaker installations at the locks. As yet, this has been carried out only at Roosteren, but the equipment of the other locks will follow in the near future. The Roosteren installation consists of four loud speakers placed both at the top and at the bottom of the lock, at distances of 150 m. The first instrument is located at the lock head, the remaining three being ranged along the mooring space. The microphone is located in the operation chamber at the lock head. In this locality any of the loud speakers can be switched in at will, dependent on the place where the vessel to be communicated with is lying. The installation was carried out by Messrs. Phillips, Limited, of Eindhoven. A third measure has consisted in increasing the staff of lock keepers. Originally, each lock was operated by one lock keeper and three assistants. The necessity of relieving the lock keeper from the locking proper, thus giving him an opportunity of devoting his time to traffic regulation, soon became apparent. At present, each lock is staffed with one lockmaster and four assistants. Besides the measures referred to above, various constructional improvements are contemplated, among which may be mentioned the provision of more spacious outer harbours near the locks. This will be effected by widening the canal on the east side. This widened section of the canal will later form the entry to a duplicate lock to be erected as soon as the traffic density dictates.

On the Juliana Canal three types of lock gates are in use: the metal-hinged falling gate type in the upper gates chamber of the locks at Roosteren and Maasbracht; mitreing gates in the lower head of these locks; and vertical lift gates in the heads of the locks at Born and Limmel. All three types have given good results in practice. During the period of severe frost in the winter of 1938-39, locking at Maasbracht and Born had to be stopped simultaneously. At Maasbracht this was due to formation of ice on the mitring gates, which increased their weight to such an extent that opening them was considered dangerous. At Born the rollers of the lift gates became frozen up, while the weight of the gates became excessive owing to ice accumulation. Long after the thaw set in, difficulties were experienced when opening the mitring gates on account of ice entering the gate recess. This had to be removed with hand tools and caused much delay. With other types no difficulty was experienced when the thaw set in. At Born, locking operations could be resumed at once.

Locking gives rise to appreciable wave formation. In the spring of the year 1936, this question was closely investigated in co-operation with the Hydraulic Laboratory of Delft University. It was observed that when the negative wave arising in the upper reach, when filling the lock at Born, reaches the harbour at Stein, a positive wave is reflected. The latter reaches the lock at Born about half an hour after the filling of the lock, is again reflected, and on arrival at Stein creates a receding negative wave, arriving at Born one hour and 4 minutes after filling commenced. Assuming a second filling to take place at this moment, an eventuality which in practice must be reckoned with, then the negative wave so created will unite with the above-mentioned secondary negative wave, the combined effect being a lowering of the water level by 30 cm. At the same time, the receding positive wave from Stein harbour, reaching the lock half an hour later, may cause a rise of the water level of 30 cm. In the event of more than two consecutive fillings taking place, each with a time spacing of one hour and four minutes, the effect on the water level would be more pronounced. In practice such a frequency of filling is not likely to happen.

In the lower reach between Roosteren and Maasbracht the positive wave created by emptying the lock at Roosteren will be partly reflected when reaching the harbour at Echt as a negative wave. Should this coincide with a filling wave from Maasbracht, then an extra deep troughed wave will result. Moreover, the possibility of a concurrence of this filling wave with an existing negative wave from previous lockings must be borne in mind. When creating these conditions experimentally, a lowering of the water level at Roosteren of 57 cm. was measured. A large positive wave may arise when the emptying wave from Roosteren coincides with an already existing positive wave and the latter is amplified at Echt by reflection of a filling wave from Maasbracht.

In practice, the following deviations from the normal water level may be expected. At the lock at Maasbracht: rises up to 45 cm. and lowerings up to 50 cm.; at the lock of Roosteren: rises up to 45 cm. and lowerings up to 65 cm.

In the middle reach between Born and Roosteren each wave passing the harbour entrances gives rise to three waves: a through wave, a receding wave and one entering the harbour. The latter is reflected at the end of the harbour and is split up at the harbour entrance into a number of secondary waves. On account of the shortness of this reach (5 km.) and the presence of the harbours, a strong oscillation of the water takes place. Immediately below the Born lock the water level undergoes the following changes after the emptying of the lock chamber: The crest of the emptying wave passes this point 5 minutes after starting emptying; the negative wave, reflected at the entrance of Berg harbour, reaches the lock 5 minutes later; the wave entering the harbour and reflected when reaching the end of it is split up at the harbour entrance and arrives at the lock 6 minutes later in the shape of a positive wave. This wave is again reflected, and the receding negative wave from the harbour entrance reaches the lock 5 minutes later. In this way, alternately, wave crests and wave troughs arise at intervals of 11 minutes. Extra high waves may occur in this reach when a filling wave from Roosteren coincides with the first reflected emptying wave from Born, and the filling wave, in its turn, coincides with an existing wave. These conditions were reproduced in practice and the following results were recorded: In the short space of time of 5 minutes, the water level at the bottom end of the Born lock descended to 40 cm. below and rose to 50 cm. above normal. Once such a wave is set up, larger deviations of the water level may easily occur. The deviations in practice to be reckoned with are: At the Born lock, rises up to 50 cm., lowerings up to 70 cm.; at the Roosteren lock, rises up to 40 cm., and lowerings up to 50 cm.

TABLE I.—Number and Tonnage of Ships Using the Juliana Canal.

	Number of Ships.			Total Tonnage.		
	1936.	1937.	1938.	1936.	1937.	1938.
Maasbracht lock ..	36,531	39,213	42,074	14,839,868	16,073,363	15,495,370
Roosteren lock	35,342	39,065	42,620	14,782,867	15,943,015	15,491,421
Born lock	31,413	34,502	42,620	11,784,338	12,576,454	12,597,846

LITERATURE.

The Medieval Fenland. By Dr. H. C. Darby. Cambridge: The University Press. [Price 12*s.* 6*d.*]

The Draining of the Fens. By Dr. H. C. Darby. Cambridge: The University Press. [Price 1*l.* 1*s.* 0*d.*]

The way in which great engineering works may endure when their creators have almost passed out of memory is well illustrated by some of the Roman roads of England. Although, apparently, the Ministry of Transport has decided that Watling-street is unsuitable for widening to the standard of a great arterial road, none the less, it is being dealt with on a modest scale and still forms one of the main highways from London to the North. The motorist of to-day, if he has imagination as he follows the road, may feel himself on the track of the Roman legions, and, with but little observation, can see where the vicissitudes of the centuries have pushed the road from its original position, to which, after local deviation, it returns. Great historic buildings apart, however, this endurance of civil engineering works may probably best be seen in the drainage works of the Fenlands. Between Whittlesey and Thorney, a few miles east of Peterborough, the road passes over Morton's Leam, a surface drain which runs south of, and parallel to, the canalised River Nene. Morton's Leam was constructed by Bishop Morton in the year 1478 and still serves a useful purpose in this complicated drainage scheme. An excellent photograph of Moreton's Leam as it exists to-day is reproduced in the first of the two books, the titles of which are given above. The history of fen drainage from Roman times up to the year 1900, which is dealt with in these volumes, is but little concerned with our ancient roads, but it is of interest to note that Ermine-street, connecting London with Lincoln, and parts of which are now incorporated in the Great North-road, bears to the west near Peterborough, in order to follow the line of the higher ground which lies to the west of the Northern Fenland. Little is known of the condition of the Fens in Roman times, but the latest tool of archæology—aerial photography—has revealed traces of many watercourses which no longer exist.

Dr. Darby's scholarly volumes not only furnish a detailed history of the successes and failures of the drainage works of the Fenlands from the earliest known times, but incidentally illustrate the gradual evolution of English governmental methods over the course of time. Some of the many setbacks and disappointments which have marred the history of Fenland drainage have been due to faulty work in the construction of the ditch banks, although, in justice to the early engineers who carried out the work, it would probably be fair to say that lack of suitable local material, and the transport and financial difficulties which prevented it from being obtained from other areas, had more to do with bank failures than had the ignorance of the constructors. A more frequent cause of the ultimate failure of drainage works, however, was the divided responsibility over the thirteen hundred square miles of country which constitute the English Fenland. The most enthusiastic and conscientious pioneers, time and again, saw their work rendered nugatory by the fact that drainage authorities or individuals in neighbouring areas entirely neglected the streams and ditches to which their

own work was necessarily related. The ill effects of this lack of controlling bodies with wide interests and responsibilities may be traced through the whole history of Fenland drainage, and, as recently as the year 1913, the late Sir Frederick Donaldson, speaking at a meeting of the Institution of Mechanical Engineers, could refer to "the apparent difficulty of control, from want of cohesion between the different bodies which have to administer the whole area . . . the go-ahead district might be restricted from giving full effect to its plans by the backwardness or niggardliness of its neighbour." The condition which these remarks describe, and which endured during the whole period covered by these volumes, was finally dealt with by the creation of the Great Ouse, Nene, Welland and Witham Drainage Boards, in 1930.

A glance at the Ordnance maps which cover North Fenland and the Bedford Level will show the whole countryside to be intersected by a system of surface drains, hundreds, probably thousands, in number, dividing it into a multitude of small areas, mostly rectangular in shape. A description of the origin and development of this amazingly complicated system is the task which Dr. Darby has set himself and which he has carried out with so much ability. In his earlier volume he carries matters to the end of the Fifteenth Century, a period which ended with the construction of Morton's Leam, the first example of large-scale drainage. Earlier years had seen much local work on a small scale, usually taking the form of reclamation on the edges of the fens in order to increase the amount of arable land. Much of this work was carried out by the monasteries. In 1196, for instance, the Abbot of Ramsey leased out Staplewere Fen for twelve years on the condition that it should be returned "with any improvements which shall be made in that fen." In the early part of the Thirteenth Century Sawtry Abbey received the gift of a messuage in Ely which Alan, parson of Bassingbourn, had "raised from the marsh at his own expense." Many similar examples could be quoted from Dr. Darby's record.

During this early period, the rivers of the fen country formed important highways and it is likely that in a period of primitive roads, when probably even the Roman highways had degenerated to mere tracks, the Witham, the Welland, the Glen, the Nene, the Great Ouse, and the Cam provided better means of communication than was available in many parts of the country. These rivers formed the great natural drains of the district, and the earliest earthworks of any importance were probably constructed in connection with their control. That civil engineering works of cognate nature were not unknown in the area is made evident by the construction of the causeways, one of which, at Ely, is associated in common memory with Hereward the Wake. It appears from Dr. Darby's researches that the topography of the Hereward legend is confused. There were three causeways at Ely, those at Aldreth, Earith and Stuntney, and it is not clear which is intended. The time of their original construction is not known, but tradition asserts that Aldreth causeway was built by William the Conqueror.

The second of Dr. Darby's volumes carries matters from the Fifteenth Century to the year 1900. The first major event which it has to record is the dissolution of the monasteries in 1536 and 1539. In view of the prominence they had taken in the work, this was a disaster from the point of view of fen drainage. Large estates were turned over to many owners, with the result that essentially self-contained works were arbitrarily broken up, while many new landowners seem to have had little regard for their responsibilities. It may reasonably be argued, however, that this was a necessary stage in the progress towards public responsibility as it is understood to-day and certainly, in due course, the idea of large-scale co-operative drainage grew up. This was particularly the case in the Bedford Level, where, before the outbreak of the Civil War in 1642, Vermuyden, the Dutch engineer, had constructed the old Bedford River, which is still such a landmark of this district. The confusion of the Civil War led to the suspension of almost all work in the area, but eventually conditions improved, and by 1651, the new Bedford River and the Forty Foot Drain connecting the River Nene with the old Bedford River had been constructed.

One of the phenomena which has caused many of the difficulties of fen drainage has been the gradual lowering of the surface of the fens. This, a direct consequence of the drainage itself, has resulted in many areas in the level of the ground to be drained falling below the level of the bed of the ditch by which the drainage water is carried. In one recorded case the ground level had fallen by some 6 ft. between 1860 and 1932. This effect, which is dealt with in considerable detail in the volume, is the main reason for the introduction of the innumerable pumping sets which are a feature of the fens, and which have progressed through the stages of wind plants and steam plants to oil-engine installations. Although Dr. Darby does not address himself specifically to engineers, there is much information in his works of both interest and value to members of this profession. The volumes are documented in remarkable detail and unquestionably at once take their place as authorities on their subject. It is fitting that treatises of such weight should come from the University of Cambridge, which itself is located on the southern part of the Bedford Level.

Timber—Its Properties, Pests and Preservation. By DR. F. Y. HENDERSON. London: Crosby Lockwood and Son, Limited. [Price 9*s.* 6*d.* net.]

IN spite of the many substitutes that have deprived timber of its former paramount position as a structural material, the innumerable other uses that have been found for it, and the natural conservatism of mankind, practically guarantee it against total displacement by new metals or by plastics; the guarantee is sealed by the general appreciation of its intrinsic virtues, ranging as they do from cheap utility to sheer beauty. No idea emerges more clearly from this book than that the variety of wood is endless; that is the particular quality of wood which makes a lucidly written book about it universally interesting. Perhaps it accounts, too, for the rather chaotic state of timber terminology, measurements and specifications, which besets whoever would deal with timber in this country to-day. Dr. Henderson has taught timber technology to engineering and building students for ten years before presenting the subject matter of his lectures in book form. Avoiding technical intricacies, he has succeeded in offering valuable information to the layman without deviating from his express intention of providing those engaged in the specification or the working of timber with practical knowledge in those branches of its technology which ordinarily lie outside their own special experience.

In the space of 180 pages, so wide a subject could only be approached in a general fashion. Skirting the related science of forestry to begin with the growing tree, the book deals adequately with the physiological structure, the strength, durability and other properties of timber, and, more briefly, with the manner of its transformation at the sawyer's hands. Ample space is devoted to the destructive insect and fungoid pests which find in it their *Lebensraum*, and to the best known methods of defeating them. There are useful chapters on timber identification and seasoning, and an appendix describes a simple method of detecting fungi in wood by means of a common microscope. Wood bending, veneers and plywood are mentioned in a chapter on miscellaneous but relevant matters, and there is a short bibliography, and a good index. Numerous, clearly annotated illustrations are always welcome in a book of this type; although the sketching of several solid figures (Nos. 5, 9, 15, 39 and 42) contravenes the laws of perspective. Several instructive paragraphs deal with the care and maintenance of household woodwork, and anyone called upon to buy woodwork, either for domestic or business purposes, is likely to do so with greater confidence for having first read this informative and well-produced volume.

PANAMA-CANAL TRAFFIC.—During the twelve months ending January 31, 1940, vessels to the number of 5,869, carrying 29,025,943 tons of cargo, passed through the Panama Canal, as compared with 5,707 ships, carrying 26,525,226 tons of cargo, during the preceding twelve months.

SOME EFFECTS OF SHORT-CIRCUITS ON THREE-PHASE TRANSMISSION LINES.

By T. F. WALL, D.Sc.

(*Continued from page* 356.)

6. *Some Transformer Relationships.*—Two of these may be considered: (i) A Three-Phase Star-Connected Transformer of which the Secondary Winding is Open-Circuited. In accordance with a well-known principle, a three-phase star-connected transformer winding of which the neutral point is insulated, cannot carry current harmonics of any frequency which is a multiple of three, since there is no return path in the winding for such harmonics. Now suppose it is required that the back e.m.f. of the transformer winding shall be a sine function of the time. For this purpose it is necessary that the rate of change of the magnetic flux which is linked with the winding shall be a sine function of the time and consequently that the flux itself shall also be a sine function of the time.

Fig. 20, page 406, shows the magnetisation curve for a transformer core, and in Fig. 21 the sinusoidally-varying flux which is required to develop the requisite back e.m.f. is shown by Φ_1. The current wave which is necessary to produce this flux wave is obtained in the well-known manner from the magnetisation curve of Fig. 20 and this current wave is shown by i_1 in Fig. 21. This current wave obviously contains a negative third harmonic component which, by analysis, has been found to be given by the sine wave i_3 in Fig. 21. Since, however, harmonics of triple frequency are not able to flow, the current wave which the mains can supply will be given by $(i - i_3)$, and this is shown by the curve i_r in Fig. 21. The actual flux which this wave of current can produce may then be obtained by reference to the magnetisation curve, Fig. 20, and is shown by Φ_R in Fig. 21. This flux wave obviously has a strong third harmonic. It follows therefore that the back e.m.f. wave which is developed by the transformer will contain a third harmonic, and although triple frequency harmonics cannot appear in the line pressure, nevertheless they will appear as a pressure between the earth and the star point of the winding.

(ii) A Star-Connected Transformer with one Phase only of the Secondary Winding Loaded.—When the secondary winding is loaded on one phase only, as shown in Fig. 22, page 406, the current I, will flow in that phase. The consequent currents which will then flow in the primary winding must be such that: (*a*) The primary current in phase C must have a return path through phases B and A. (*b*) The total power supplied to the three phases of the primary winding must be equal to the power supplied by the single loaded phase of the secondary winding.

These requirements are satisfied by the current conditions shown in Fig. 22. The vector relationships for the primary pressure and current are shown in Fig. 23, from which it will be seen that the power supplied to the individual phases of the primary windings is given by the expressions, respectively,

$$W_C = V_C \tfrac{2}{3} I;\ W_B = V_B \cdot \tfrac{1}{3} I \cos 60 \text{ deg.};\ W_A = V_A \tfrac{1}{3} I \cos 60 \text{ deg.},$$

so that the total power supplied to the primary winding is

$$W = W_A + W_B + W_C = V_C \cdot I,$$

and this is obviously also the power delivered to the load of the single phase of the secondary winding.

Now it will be observed that the current in each of the primary phases A and B is uncompensated by any current in the corresponding phases of the secondary and similarly, that one-third of the current in the loaded secondary phase is uncompensated by the current in the corresponding primary phase A. It follows, therefore, that there will be uncompensated currents in the transformer windings, as shown in Fig. 24. The flux due to these currents cannot become established in the main magnetic circuit because reference to Fig. 23 shows that these currents are all in phase. The consequence is that the corresponding fluxes will

EFFECTS OF SHORT-CIRCUITS ON TRANSMISSION LINES.

Fig. 20.

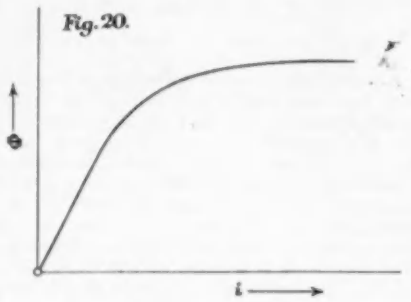


Fig. 21.

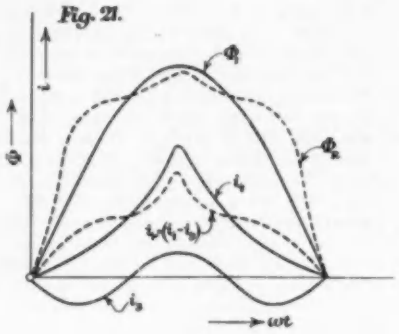


Fig. 22.

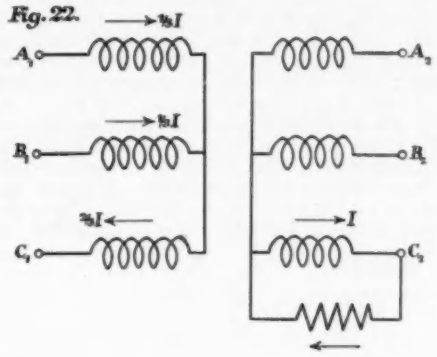


Fig. 23.

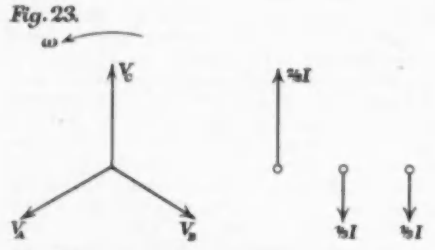


Fig. 25.

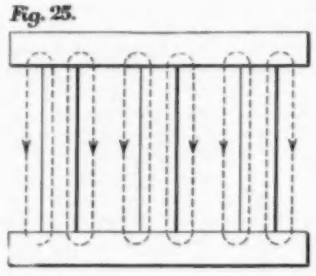


Fig. 26.

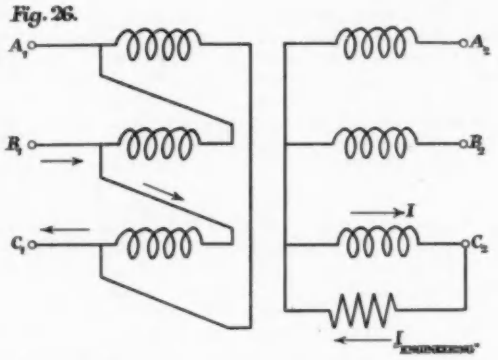
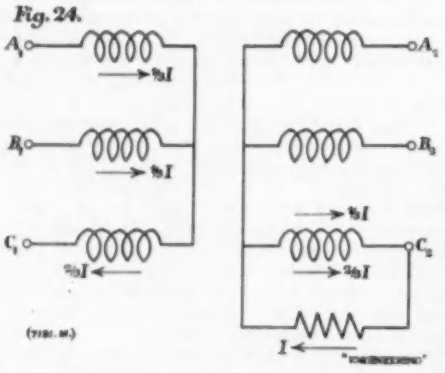


Fig. 24.



appear as leakage fluxes between the yokes of the transformer, as shown in Fig. 25.

The air flux produced by these currents, each of magnitude ⅓ I, will give rise to serious heating in neighbouring masses of metal, such as the iron containing vessel of the transformer and, in practice, the magnitude of these currents should not be allowed to exceed about 10 per cent. of the normal full-load current of the transformer. This then, sets a limit to the load which can be connected across one phase and the star point of a transformer. If the transformer is built with 4 cores or with 5 cores, the fluxes due to the uncompensated currents of magnitude ⅓ I will then have a path through these additional cores and the back e.m.f. of the transformer will be heavily reduced, so that in such cases any loading of a single phase to the star point is impracticable.

7. *Practical Methods which Permit the Loading of a Single-Phase Star-Connected Transformer Secondary Winding.*—In many practical cases, such as for three-phase four-wire distribution systems, it is essential that the loading of one phase of the secondary winding shall be possible up to the full rated value of the transformer output. For such purposes, several arrangements of the transformer windings are available.

(*a*) If the primary winding is mesh-connected, the currents in the primary windings of the transformer can flow so as fully to compensate the current in the loaded secondary phase without calling into existence any currents in either of the other two phases of the primary winding. In this way, it is possible to load one phase of the secondary winding across the star point up to the full rated output of the transformer. The conditions in this case will be understood by reference to Fig. 26.

(*b*) Another way in which the unrestricted loading of one phase to the star point may be obtained is to provide a special three-phase winding on the transformer cores which is mesh-connected and short-circuited on itself. This is known as a tertiary winding and it provides paths for the currents ⅓ I, which are developed when both primary and secondary windings are star-connected. The operation of this system will be clear from an inspection of Fig. 27, on the opposite page.

(*c*) A further method which is available for loading one phase of the secondary winding to the star point is by means of a "zig-zag" secondary winding, sometimes called an inter-connected secondary winding. This secondary winding is shown in Fig. 28, and comprises two equal portions which are connected together as shown in the diagram. With this connection the secondary voltage per phase is only 0·866 of the value which it would have if all the turns of each phase of the secondary were connected in series in the normal manner.

8. *Treatment of Short-Circuit Problems by Means of a Phantom E.M.F.*—When a single-phase system is normally insulated and connected to a supply pressure E, the earth potential will be mid-way between the potentials of the two lines A B, Fig. 29. Between each line and earth there will be a distributed capacitance C_e and between the two lines a distributed capacitance C_l. In what follows, the capacitance current due to C_l will be neglected, since this current will not be affected by the short-circuit of one line to earth. Reference to Fig. 30 shows that the charging current in the line due to the earth capacitance will be

$$I = E\ \omega \frac{C_e}{2} = E\ \omega \frac{c_e\, s}{2} \text{ amperes,}$$

where C_e is the total value of the distributed capacitance to earth of each line; c_e the capacitance to earth per unit length of the line, and s the length of the line. In Fig. 31, the current distribution in the line is shown diagrammatically.

If, now, some point M on the line A, Fig. 32, is short-circuited to earth, this means, of course, that the pressure between the line A and earth becomes zero, so that the full pressure E will then exist between the earth and the line B. The total capacitance current between the earth and the line B will then be

$$I = E\ \omega\, C_e = E\ \omega\, c_e\, s \text{ amperes,}$$

and this current will appear as an earth current, as shown in Fig. 32. It is seen, therefore, that in this simple case of a single-phase system, the calculation of the earth current due to a short-circuit to earth on one line is a very simple problem. In the case of three-phase systems however, it becomes a much more difficult matter to calculate the earth currents when such a direct method is used. In such cases, a notable simplification of the problem is achieved if the device of introducing a phantom e.m.f. is used, and this can be well explained by applying it to the case of the single-phase system already considered.

Suppose, in Fig. 34, an e.m.f. $\frac{E}{2}$ is injected between the earth and the point M and superposed on the normal line pressure to earth so that the injected e.m.f. is at every moment equal and opposite to the normal line pressure. The effect of this e.m.f. superposed on the normal line pressure is to bring the potential of the line A to earth potential and to raise the potential of the line B to the pressure E between the line and earth, so that the resultant pressure relationships will be the same as shown in Fig. 32 for the case of a short-circuit to earth at M.

The actual current distribution may then be found for the following conditions: (i) That the line is normally insulated and the line pressure acts symmetrically between the lines, as shown in Figs. 31 and 33. (ii) That the injected e.m.f. $\frac{E}{2}$ at M is the only e.m.f. acting in the system, as shown in Fig. 34.

If these two separately obtained current distributions be then superposed, the current distribution so obtained will be that which actually exists in the system when one line is short-circuited to earth, as shown in Fig. 32. Since, however, no earth current will normally flow in the fully-insulated system, it follows that the earth current when one line is short-circuited will be that which is obtained from the assumption that the injected e.m.f. $\frac{E}{2}$ is acting alone in the system, as shown in Fig. 34. This device of assuming an injected e.m.f. at the point of short-circuit to earth—which may be termed the "phantom e.m.f. method"—immensely simplifies the treatment of short-circuit problems in the case of three-phase systems, although, as will be apparent from the foregoing, there is not much advantage in its application to the simple case of a single-phase system.

(*To be continued.*)

EFFECTS OF SHORT-CIRCUITS ON TRANSMISSION LINES.

(*For Description, see Opposite Page.*)

Fig. 27.

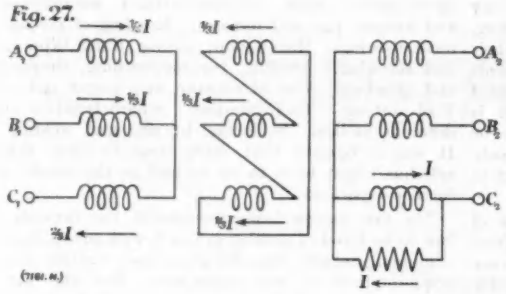


Fig. 28.

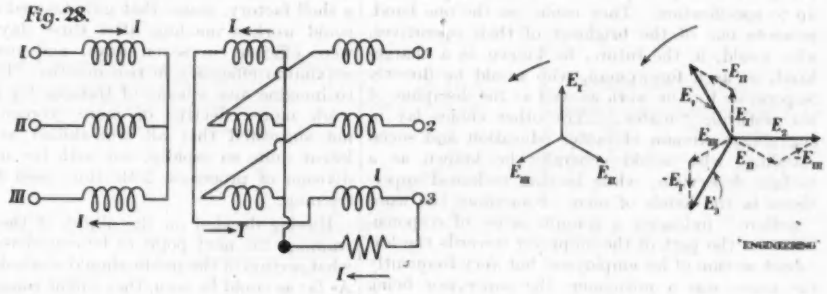


Fig. 29.

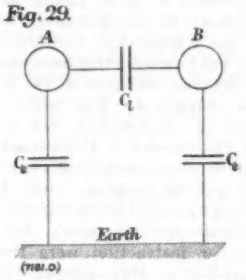


Fig. 30.

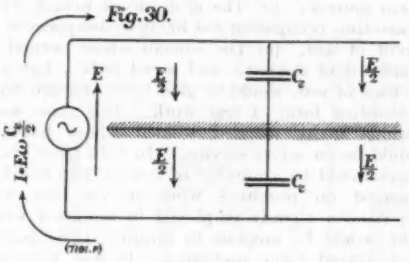


Fig. 31.

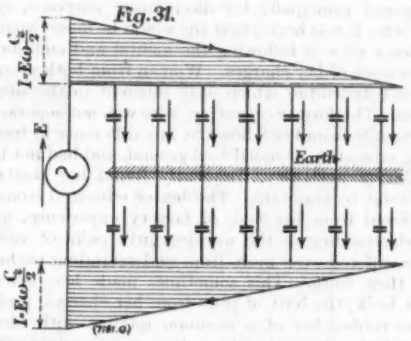


Fig. 32.

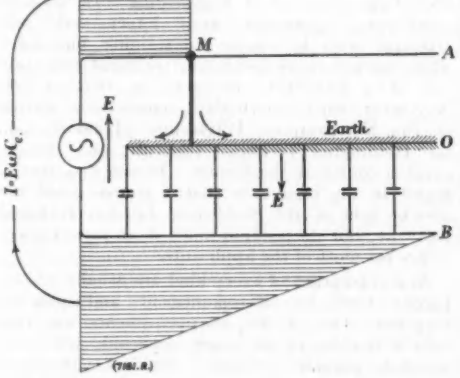


Fig. 33.

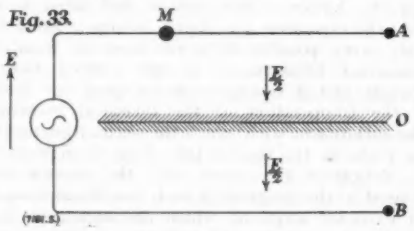
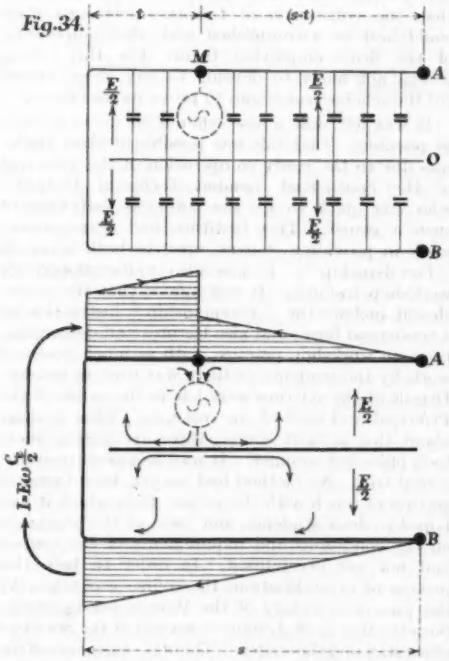


Fig. 34.



WOMEN AND MUNITION WORK.

By MISS V. HOLMES, A.M.I.Mech.E.

IT is not always safe, as we are now learning, to forecast the course of events in the present war from our experiences in the last one, yet certain forecasts seem to be almost in the nature of a mathematical certainty. One is that unless there is an early peace, our production of armaments, munitions and war material generally, will have to be at least as great as in the years 1914 to 1918, while the call on our manhood will certainly be no less. In all probability, our munitions requirements will have to be many times greater, since we are fighting this time with only one ally against an even more highly prepared enemy, and because mechanisation has developed out of all recognition in every branch of warfare. Also, if we are to avoid bankruptcy, it is essential that as much as possible of our supplies should be made in this country, rather than bought overseas. This means that women will have to be employed in engineering workshops to as great an extent, as in the last Great War and probably to a far greater extent. The recognition of this fact brings with it the problem of what can be done to prepare for this eventuality. Here, since human nature does not change, or at all events does not change rapidly, we cannot afford to ignore the lessons of the last war. Perhaps, for this reason, I may be allowed to give some impressions and conclusions derived from my own experience, between 1916 and 1918, both as an operative, and as a superintendent of female labour. I believe that my views do not differ in essentials from those of other women who have had similar experience. My most definite impression is that women did their best work in all-women shops, under the control of charge-hands and supervisors of their own sex. For one thing, their attention was less likely to be distracted from their work than in a mixed shop. For another, when men and women work side by side in an engineering works, there is always a tendency for the latter to suffer from a sense of inferiority. A girl, confronted with unfamiliar work, may say to the man working beside her, "I don't think I shall ever be able to do this," to which he replies, "No, I don't suppose you will, it isn't really women's work." He comes to her rescue, and the girl cannot be blamed if she continues to play the helpless female. This rôle, as every woman knows, can, on occasions be both pleasant and restful, but it is not helpful to engineering output. The same girl, finding herself in an all-women shop, and seeing another girl doing the work she is about to attempt, thinks, "If she can do it, I can." If her charge-hand is also a woman, the job no longer appears occult or alarming, on the principle that "What woman has done, woman can do." The seeds of ambition are often sown, and with the right guidance, she learns to take an interest in her work, and a pride in her skill.

New female labour, in my experience, was more smoothly absorbed, and discipline was better maintained, under the right type of forewoman than under a foreman. Possibly this was because women are good psychologists where members of their own sex are concerned, and know that with them a word in season may serve to avert serious troubles at a later date. Another point, which I think will be generally conceded, is that the type of leadership they are given has a greater effect on the more highly-strung women. I can remember, one day, finding a small group of girls, who usually worked briskly and cheerfully, carrying on their work in a lethargic and dispirited way. When I asked them what was the matter, one of them replied: "Miss C. is away" (mentioning a popular charge-hand), "and it don't seem right without her." One has only to try and picture a male apprentice moping over the absence of his charge-hand, to realise that personal leadership plays a comparatively greater part in the life of the factory girl. I would not for a moment suggest that all forewomen were good, for certain ones were bullies, and others were so obsessed with the question of output that they neglected the human side of their work, forgetting that it is one of the most important factors whereby good output is maintained. Yet when the right woman could be found, the shop was conspicuously happy and orderly, and its output was invariably good.

The majority of employers gradually came to the conclusion that the supervision of women was best accomplished by women. They were then faced with the difficulty of finding suitable individuals with the necessary qualifications. A long specification of these qualifications could easily be drawn up; it would include technical ability, organising power, knowledge of factory administration, tact, firmness, dignity, etc., etc. To find women, however, in

whom all these qualities were combined, was far from easy in an industry to which women had only recently been admitted. Usually the choice had to be made from one of two groups, neither of which was likely to yield candidates fully coming up to specification. They could, on the one hand, promote one of the brightest of their operatives, who would, in the future, be known as a charge-hand, or as a forewoman, who would be directly responsible for the work as well as the discipline of her erstwhile "mates." The other choice lay in engaging a woman of better education and social standing, who would generally be known as a welfare supervisor, while leaving technical supervision in the hands of men. Sometimes the word "welfare" indicated a genuine sense of responsibility on the part of the employer towards the less robust section of his employees, but very frequently the name was a misnomer, the supervisor being engaged principally for disciplinary purposes, and because it was hoped that she would be more capable than a man of following the mental and emotional processes of her charges. Women from both groups found difficulties which were inherent in the situation. The former operative, who was not separated generally from her fellows by any difference in training, education or social background, and had not the habit of authority, frequently found her position difficult to maintain. The better educated woman suffered from her lack of factory experience, and understanding of the working girl's point of view; she suffered even more from understanding nothing of their work. This sometimes made her, behind her back, the butt of jibes from her charges, and it also robbed her of a common interest with them, on which a natural and unself-conscious relationship might have been based. In both classes there were individuals who triumphed over these difficulties, by virtue of outstanding personality, but the majority were conscious of handicaps and shortcomings, which suitable training would have gone a long way to remove.

I would summarise my opinions, formed as the result of my observations in the last war, as follows: (1) Women employees should, if possible, be accommodated in shops by themselves or, where this is not possible, in groups. (2) Their control and engagement should be in the hands of women. (3) Where possible, technical and disciplinary supervision should be in the hands of the same woman. (4) Where, on account of the complexity of the work, women in positions of responsibility cannot be in full technical control, they should nevertheless know as much about the work as possible, and about factory organisation and planning, and be encouraged to take as large a share in production as their capabilities allow.

An effort may now be described which is being made to give to women of the right type such training as will fit them for positions of responsibility in munitions works. About a year ago, as a result of recent happenings in Europe, the technical societies of this country were seeking means whereby to make a contribution to national defence. The Women's Engineering Society, like many others, had compiled a register of the qualifications and present employment of its members, but this register revealed the fact that the majority of members were already employed in firms engaged on Government work, or likely to be so engaged in the event of war. The Society was, therefore, open to consider other ways of increasing its usefulness, and it thus happened that the suggestion of training women outside the profession was sympathetically received. From the first it had the warm encouragement and support of the present President, Miss Caroline Haslett, C.B.E. It was decided that the training should aim at fitting women who had the right personal qualifications for responsible positions in engineering works—such positions as those of charge-hand, forewoman, supervisor or superintendent. Some of the reasons for making this the aim have already been given. One reason for limiting the training to those destined for such posts was the negative one that to train the rank and file of women munition workers would have been a task of too great magnitude to be attempted. An equally cogent one was that, in the opinion of those responsible for the proposal, such training was not necessary. In the last war, the usual practice was to allocate a newly-engaged and untrained girl to a machine tool which was being operated by an experienced hand. An article in ENGINEERING* written in 1916, describing a shell factory, states that girls trained in this way could work a machine after three days' training, were efficient in seven days, and reached their maximum efficiency in two months. It is difficult to imagine any scheme of training for semi-skilled work more effective or more economical. It is not suggested that all semi-skilled work can be learnt quite so rapidly, but with the modern subdivision of processes, little time need be spent in training.

Having decided on the object of the scheme of training, the next point to be considered was from what section of the public should students be drawn. As far as could be seen, they might come from three main sources:—(*a*) The professional woman whose peace-time occupation was likely to disappear in the event of war. (*b*) The woman whose normal life consisted of domestic and social duties, but who, in time of war, would be glad to be engaged on an interesting form of war work. This class would include many married women whose husbands would be on active service. (In both these classes there would be a number of women who had been engaged on munition work in the last war.) (*c*) Women already employed in munition works, who would be anxious to improve their position and extend their usefulness. It was recognised that the enlistment of the last-mentioned class could best be accomplished with the co-operation of the firms employing them. For this reason it was not likely to develop to any great extent till the scheme had begun to prove its usefulness.

It was felt that a start should be made as soon as possible. That this was possible at short notice was due to the ready co-operation of the Principal of the South-East London Technical Institute, who was quick to see the potential usefulness of such a course. This Institute had done pioneer work in providing courses, open to both sexes, in "Foremanship"; it was also well-equipped for workshop training. It was agreed that the course should include the "Foremanship" instruction in a condensed form, and also lectures and demonstrations on workshop practice, with as much practical work by the students as there was time to include. Details of the syllabus were left in the hands of the Principal and staff of the institute. Thus it came about that a short course, three evenings a week, took place last summer. It was, in a great measure, a trial trip. No method had, as yet, been found of getting in touch with the public, from which it was hoped to draw students, and views of the organisers on the conditions and requirements of the courses had not yet crystallised. In order to help this process of crystallisation, the course was taken by the present secretary of the Women's Engineering Society, Miss A. S. Lockhart, several of the Society's office staff and the writer. The other members of the class were, for the most part, members of the Society who considered that the course might ultimately be useful to them in their own firms, and friends of members.

The result of the first course was to confirm the organisers' belief in the usefulness of the scheme, for it showed how much could be learnt in a comparatively short time. The only criticism which resulted, if criticism it can be called, was that not enough time had been available for machine-shop and fitting work by the students. It was decided, therefore, that in future courses two-thirds of the time should be given to workshop instruction and practice and one-third to "foremanship." The following syllabus, which was then drawn up, was based on the instruction given in the South-East London Technical Institute.

Foremanship.—Primary duties of the supervisor or forewoman. Place in the factory administration. Relations with other executives. Elements of industrial psychology. Obligations of the employer to the employee. Remuneration and incentives. The handling of "difficult" workers. Consideration of everyday problems and specific cases. Organisation for production efficiency. Process lay-out. Systems of control of tools and materials. Progress work. Inspection. Elements of rate-fixing and estimating. Motion study and time study.

Elements of Workshop Practice.—Use of measuring instruments: scale, calipers, vernier, micrometer and gauges, jigs and fixtures. Reading of mechanical drawings. Marking-out, sawing, filing, tapping and screwing. Drilling, turning, milling, shaping and grinding. Use of capstan and turret lathes. Tool setting. Tool grinding. Characteristics of different metals. Soldering, brazing and welding. It was recognised that, from time to time, this syllabus might have to be revised as the result of further experience.

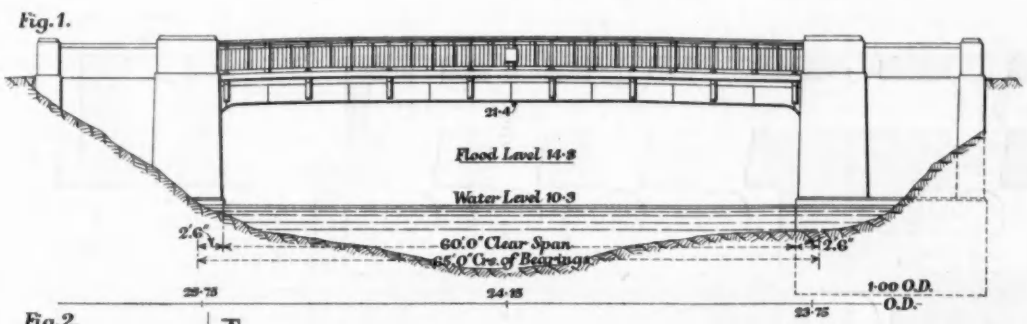
The first course being completed, the difficulty had to be faced of getting in touch with prospective students, outside the Society, and outside the acquaintances of the organisers. For the fact that it was possible to do so, thanks are due to the daily Press (both in London and the provinces), because, at the end of July and the beginning of August, they published a letter from those interested setting out the aims and how it was proposed they should be accomplished. This letter brought in a large number of applications and inquiries from all parts of the country. Unfortunately, only in London and in three industrial centres, Glasgow, Manchester and Birmingham, was the response sufficiently concentrated to offer hopes of collecting enough students for a course. In Manchester, no facilities for instruction were then available. The same applied to Birmingham, though, in the latter city, it is understood that a course is now in progress, having the same object, but run on different lines. In Glasgow, however, the position was more favourable, and a course was given at Stow College School of Engineering. In London, meanwhile, applicants were interviewed, and attempts made to arrange for training, but, for a while, as will be remembered, technical education was at a standstill. However, in October and November, three-month day courses were started at the Northampton Polytechnic (London), and the Paddington Technical Institute, and also an evening course at the former. It was a matter of regret to the organisers that a course could not also be held at the South-East London Technical Institute, but its position made it an inconvenient centre for most of the applicants.

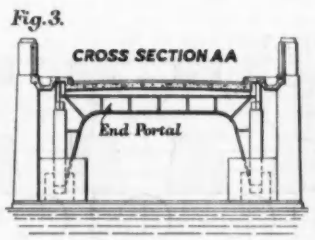
New enterprises of every kind are usually accompanied both by disappointment and pleasant surprises. One of the disappointments was that only a fraction of the eager applicants who were selected actually became students. In most respects, however, the scheme had fared better than the organisers had dared to hope. From the first, every possible help was received from the Education Department of the London County Council, and it is impossible to speak too highly of the co-operation of the technical institutes. The enthusiasm with which the authorities tackled the problem, the trouble they went to in planning the details of the course, and the interest they evinced in the progress of each individual student, far exceeded anything which the organisers were entitled to expect. They may not have been prepared for the abysmal ignorance of all things mechanical with which some students embarked on the course. They may have been somewhat disconcerted when a woman referred to a screw as "this nail-thing" or another to the driving belt of her machine as "those straps that go up and down," but they never made the mistake of confusing ignorance with stupidity. By careful planning and sequence they made what might so easily have been a smattering into a good grounding. Perhaps the most gratifying discovery of all has been the degree of keenness which developed in the students themselves as the courses proceeded, and the intense interest and pleasure which they found in acquiring knowledge and skill. The lectures included under "foremanship" also evoked great interest, and were frequently followed by a lively debate. Again and again the students have expressed their warm appreciation of the classes and their regret at their conclusion. The two day-time courses were followed almost immediately by similar ones both at the Northampton Poly-

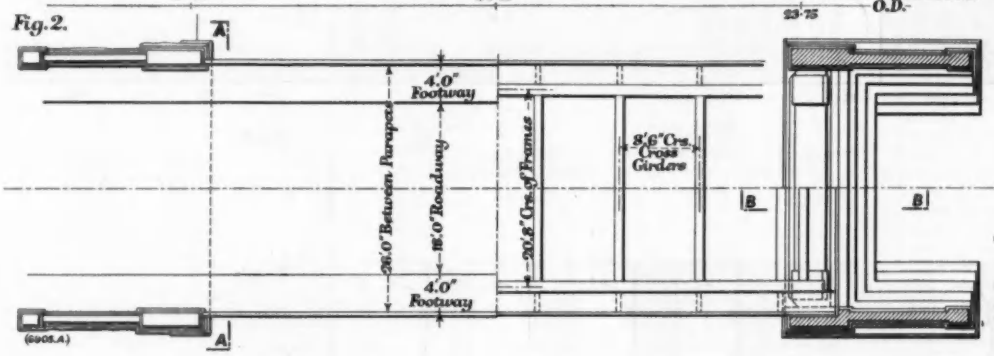
* See ENGINEERING, vol. 101, page 78 (1916).

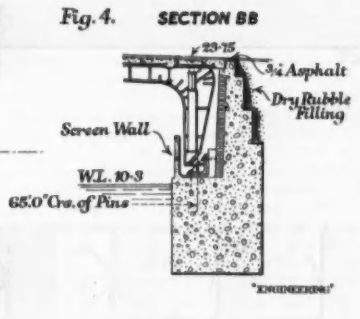
ALL-WELDED ROAD BRIDGE AT CLAYHITHE, CAMBRIDGESHIRE.

MR. A. E. PEAKE, COUNTY SURVEYOR.









technic and the Paddington Technical Institute. Since there is now a fairly long waiting list of applicants, it may be possible to start another course in London before long.

While well-planned practical work is regarded by the organisers as the most essential part of the training, the following questions, taken from the examinations set by the Institutes, give an indication of the subject matter of the lectures. The papers were written by students of varying ability, but all showed a thorough understanding of the essential points involved.

Describe three methods by which a taper may be produced on a lathe. Discuss the relative advantages of each of these methods.

How would you determine the suitability of a capstan lathe for the manufacture of a given part? What is meant by the overlapping of operations on such a lathe?

The particular form of Vee-block shown is partly produced by gang-milling. Explain this process fully, and show a set-up using common types of cutter.

Show by a line chart, a typical staff arrangement for a modern engineering works.

Describe in detail the most common forms of wage payment systems, mentioning at least one advantage and disadvantage of each.

The basic time for a particular operation is ten minutes. Calculate the time allowance on any two of the wage payment systems you have mentioned in order that the worker may be able to earn 20 per cent. above his day-work rates.

Students have always been given to understand that at the conclusion of the course they must expect to work for a period as ordinary operatives, in order to acquire factory experience, before securing more responsible positions. It is believed that the principle of serving in the ranks before obtaining a commission is a sound one. In practice, however, owing to the applications which the Society has received for women with some measure of training, many start with a position correspondng to that of, say, lance-corporal. The majority are set aside from the first for special training to fit them for technical responsibility. In some cases, where trainees have obtained operatives' jobs through the labour exchange, they have been promoted in a few weeks; in two cases the original wages have been doubled. Some are being specially trained for tool-setting, and others are being used for quite responsible inspection work. One is being trained for research work in connection with aircraft. Firms who are employing the trainees ask for more, which is perhaps the best evidence of the value of the scheme. While there appears to be no lack of opportunities in the south, the trainees in Scotland have not been so fortunate. It is hoped to find openings in other districts for such of them as can leave their homes. The success of the first batch of London trainees suggests that there is not much amiss with the scheme or the syllabus. The only modification to the latter which has so far been made is the addition of "Workshop Mathematics" to the curriculum.

Reviewing the scheme as a whole, the chief matter for regret appears to be that it is on too small a scale, so that it may be anticipated that the supply of trained women will soon be quite inadequate to the demand. Nevertheless, the movement is growing, and new developments are on the way. It must be remembered that what has been accomplished has been done without funds or Government backing. Students have had to pay their own fees, and, though these may be considered small for the value received, they have also, in the case of day students, had to support themselves without earning for the period of their training. Some have put their entire savings into doing so, and in one or two cases have been obliged to take employment without finishing the course. Thus the organisers are faced with the task of securing students with a degree of intelligence above the ordinary, in competition with other war openings which offer free training and board and lodging. The organising has been done by a secretary who was already very fully occupied before the scheme materialised, and by members of the Society (and of its daughter organisation, the Electrical Association for Women), who were already in full-time employment. Those responsible cannot but be conscious that much more might be done to open up the possibilities of the scheme by a full-time organiser. One hoped for development shows signs of taking place: that of the awakening of interest on the part of employers in the idea of providing training for picked operatives. It is believed that to take one of the courses would give such women a firmer basis for their knowledge, and a broader conception of their duties. The mere fact of having taken a special course would give them prestige with their fellow workers. In a busy firm, few people have time to teach, and experience has led the organisers to the conclusion that those teach best who have made teaching their profession. A number of problems still await solution, and among these may be mentioned the question whether a more advanced course should be provided for those students who can afford to spend a few additional weeks on instruction, and for the operatives who have already been mentioned. Another question is whether more specialised training should be provided for certain branches of the engineering industry, such as electrical engineering and aircraft construction.

Yet another problem is that of meeting a growing demand which appears to exist for capstan tool-setters, the great difficulty in this case being that most technical institutions have, at most, one capstan lathe, and that frequently far from modern in type. The organisers would be grateful if experienced engineers would express their views on these and other problems. In conclusion, it may be stated that the greatest difficulty of all is still that of collecting a sufficient number of the right type of student in districts where facilities for their training are available.

ALL-WELDED ROAD BRIDGE AT CLAYHITHE.

A NEAT example of the application of welding to bridge construction is provided by the road bridge recently built for the Cambridge County Council at Clayhithe, about 4½ miles north-east of Cambridge, where the Waterbeach-Horningsea road crosses the River Cam. It takes the place of a former toll bridge, which consisted of two lattice girders from which were suspended shallow cross girders carrying a concrete deck. The carriageway of the old bridge was only 10 ft. wide, however, and the permitted load was only 3 tons, while the approach gradients were rather undesirably steep. The last-named feature, coupled with the necessity that the existing road levels and the clearance above water level should be maintained, was a deciding factor in the selection of the portal-frame design illustrated in Figs. 1 to 4, on this page, and Figs. 5 to 12, on page 414. It was desirable, also, in this locality, that the new bridge should have a clean and pleasing outline, a characteristic which was one of several advantages offered by the use of a welded construction.

The new bridge consists of two portal frames with solid webs, supported at the ends on hinged bearings

DUPLEX DOUBLE-ACTING HORIZONTAL OIL PUMP.

MESSRS. HAYWARD-TYLER AND COMPANY, LIMITED, LUTON.

(*For description see Opposite page.*)

Fig. 7.

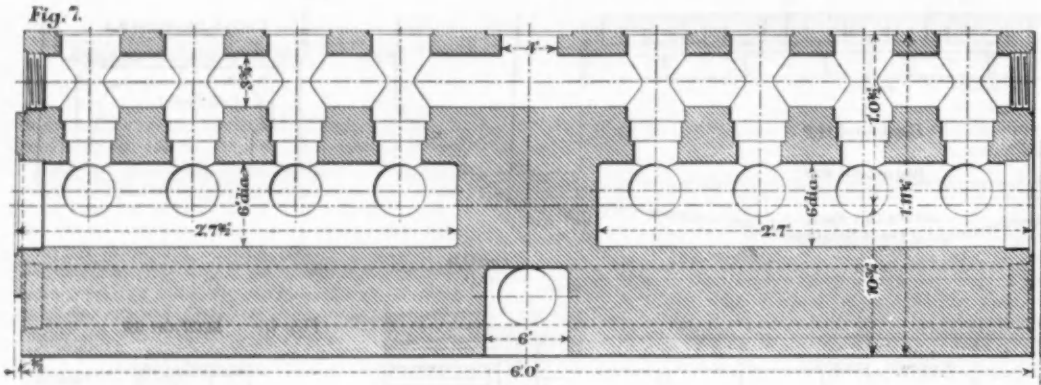


Fig. 8.

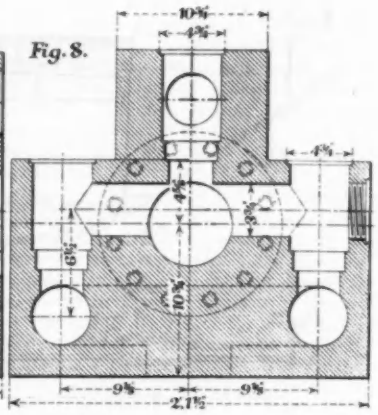


Fig. 9.

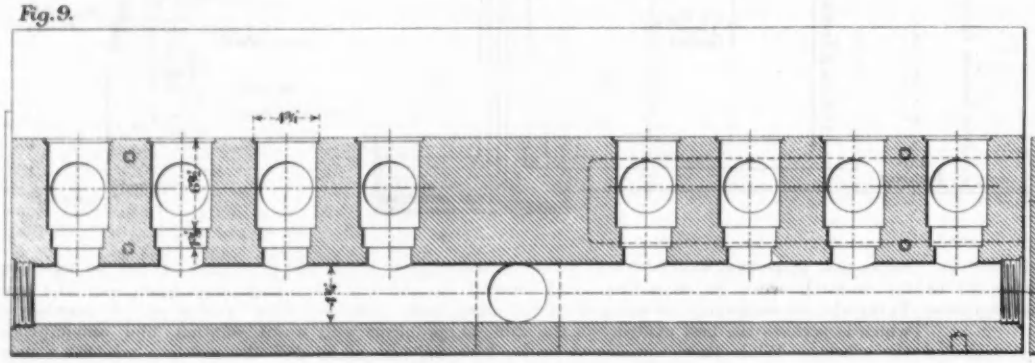


Fig. 10.

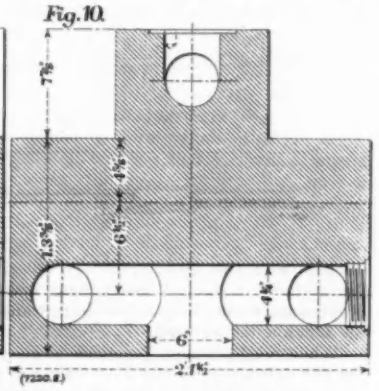
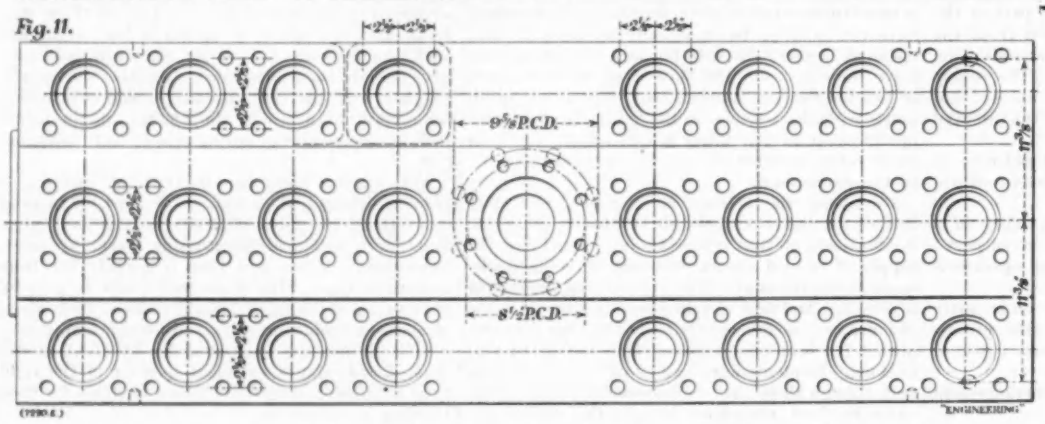


Fig. 11.



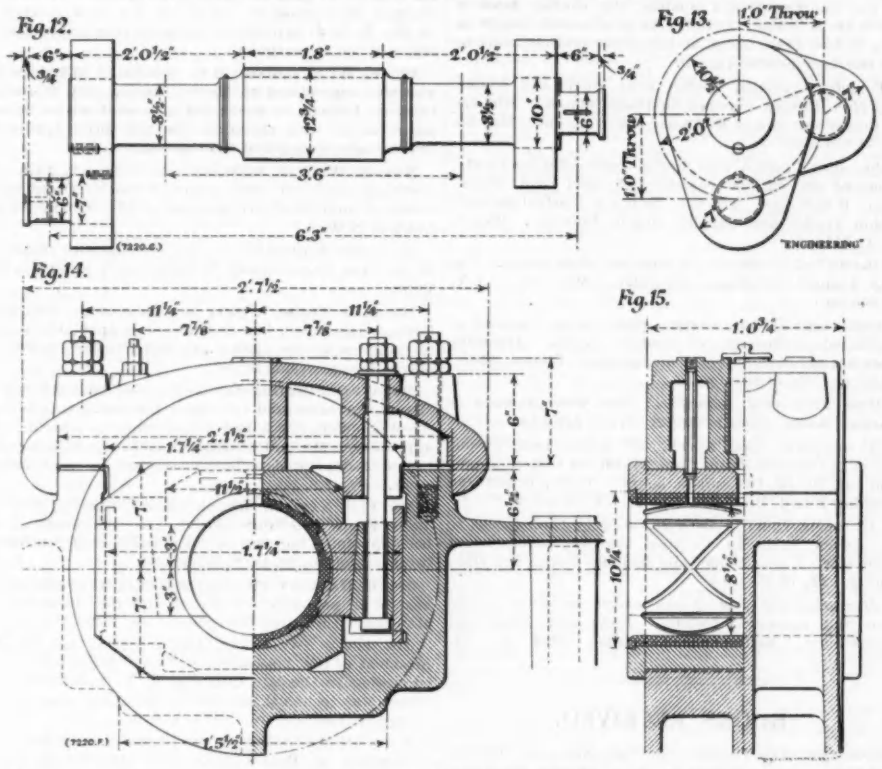
placed at 65-ft. centres. The span is 60 ft. between abutments, and the total width of 26 ft. provides for two 4-ft. footpaths as well as a carriageway 18 ft. in width. The construction depth of the main frames at mid-span is only 2 ft. 6⅞ in., and this design enabled the bridge to be built as a deck structure without the girders projecting above the road level. The main frames carry cross-girders spaced at 8 ft. 6 in. centres, on which is supported the reinforced-concrete deck of the carriageway. The two footways and the hand-railing are carried on cantilever brackets placed at the ends of the cross-girders. The main frames are connected at their ends by two smaller portal frames, one of which is clearly seen in Fig. 10. The abutments, of straightforward design, consist of concrete faced with brickwork and filled, under the approaches, with dry rubble. Light screen walls are built on the river side of the abutments to protect the bearings. The design of the roadway conforms to the standard Ministry of Transport loading for highway bridges, and the footways are constructed to carry a continuous load of 100 lb. per sq. ft.

The details of the main frames are shown in Fig. 5, page 414, from which it will be seen that they consist of top and bottom flanges, 14 in. wide, connected by ½-in. web plates, 2 ft. 3 in. deep. The top flange comprises five plates, that in the centre being 28 ft. long and 2¾ in. thick, and the others, 1½ in. thick. The plate on each side of the centre plate is 9 ft. 6 in. long. The outer plates are bent to an inside radius of 2 ft. 3 in. to form the outer flanges of the vertical legs of the frame. The ends of the adjacent plates are chamfered to include an angle of 70 deg., the edges at the root of each Vee weld being ¼ in. apart. The ends of the centre top plate are bevelled at an angle of 1 in 5, down to the 1½-in. thickness of the adjacent flange plates. The bottom flange is 1½ in. in thickness, and consists of only three plates, the centre one being 22 ft. 6 in. long. Those on each side of it are bent to an inside radius of 3 ft. to form the haunches. The central web plate is 46 ft. 8½ in. long, the vertical joints with the adjacent web plates, therefore, being situated equidistantly between the joints in the top and bottom flanges, respectively. The web is connected to the flanges by ⅜-in. fillet welds. Intermediate stiffeners of ½-in. plate, 6 in. wide, are worked between the flanges at spacings of 2 ft. 1½ in., alternately on the inside and outside of the web, and are attached to the flanges and the web by ½-in. fillets. Additional stiffeners of 1-in. plate, 6 in. wide, are fitted radially to the inside and outside flange curves at the haunches, the attachment here being by ½-in. fillet welds. Further stiffening of the curved flange plates and web is provided by 1-in. triangular gussets adjacent to the 1-in. by 6-in. stiffeners, and, in the vertical legs of the frame, by two ¾-in. horizontal diaphragm plates; all of these are attached by ½-in. fillet welds. It should be mentioned here that the main spans were given a dead-load camber of ¾ in. during construction. The eight cross-girders, to be seen in Fig. 11, page 414, consist of 10-in. by 1-in. top and bottom flanges, with a web of ⅜-in. plate, 16 in. deep. The flanges are welded to the web with ¼-in. fillets, and the girders are attached to the main frames at their ends by cleats of 3½ in. equal angle, for erection purposes, and by ½ in. fillet welds, which are also carried round the cleats. The spaces between the top flanges of the cross-girders, at their ends, and the underside of the top flanges of the main frames are filled with rolled-steel Tees, 8½ in. long, formed by splitting 12 in. by 5 in. joist down the neutral axis. These fillers can be seen in place in Fig. 12. The small portal frames at the ends of the bridge, a detail of which is shown in Fig. 6, on page 414, have top and bottom flanges 10 in. wide and ⅝ in. thick, and webs 22 in. deep and ½ in. thick. The flange plates are joined by single-Vee welds, similar to those of the main-frame flanges, and the lower flange is curved to an inside radius of 2 ft. 3 in. The through stiffeners in this case are ½ in. thick. The end-portal web is attached to the main-frame web by ½-in. fillets, and is strengthened on the outside of the main web by split 12-in. by 5-in. rolled-steel joists as shown. The cantilever brackets supporting the footways have webs ⅜ in. thick, and 5 in. by ⅜ in. flanges. At their outer ends, they are connected by a continuous 10-in. by 3½-in. channel, forming a fascia on which the handrailing is mounted. The roadway consists of an 8-in. reinforced-concrete slab, on which is laid a 2-in. asphalt carpet, bounded by 8-in. by 6-in. precast concrete kerbs. The surface of the footways is also of asphalt, 1 in. thick. Beneath each footway there is a trough, 16 in. wide and 9 in. deep, lined with ¾-in. asphalt, for the accommodation of pipes and electric cables.

An interesting feature of the erection of the bridge was the pre-stressing of the main frames. The frames were erected on their bearings, in which they rest on mild-steel pins, 4 in. in diameter and 12 in. in bearing length, and at one end of the frame a horizontal thrust of about 8 tons was imposed by means of hydraulic jacks, to ensure that the stresses under the dead weight of the steelwork were in accordance with the calculations. The general contractors for the construction

DUPLEX HORIZONTAL OIL PUMP.

MESSRS. HAYWARD-TYLER AND COMPANY, LIMITED, LUTON.



of the bridge were Messrs. Henry Bolton and Company, Limited, Birmingham, and the steelwork was supplied by Messrs. Braithwaite and Company (Engineers), Limited, Newport, (Mon.). The welded work throughout the contract was carried out generally in accordance with British Standard Specification No. 538 for Metallic-Arc Welding. We understand from Mr. A. E. Peake, the Cambridge County Surveyor, to whom we are indebted for facilities in preparing this description, that the total cost of the structure, including the approach roads and incidental works, was 8,855*l*.

DUPLEX DOUBLE-ACTING HORIZONTAL OIL PUMP.

THE handling of oil in bulk for distribution through pipe lines involves the use of large pumps, capable of pumping against a considerable head, and an order was recently placed with Messrs. Hayward-Tyler and Company, Limited, Luton, by Messrs. The Asiatic Petroleum Company, for four duplex double-acting horizontal pumps, each having a capacity of 16,500 gallons per hour at a working pressure of 855 lb. per square inch. Three of the pumps will be steam driven, while the fourth, illustrated in Figs. 1 to 15, on this and the opposite pages and on Plate XXII, will be driven by a gas engine operating on natural gas. It may be mentioned that the three steam-driven pumps are similar to the pump illustrated. Fig. 1, Plate XXII, shows the latter under test in the maker's works prior to shipment to Praboemoelih-Pladjoe, Sarawak. It was tested with the actual engine by which it will be driven on site, a 330-brake horse-power six-cylinder engine supplied by Messrs. The National Gas and Oil Engine Company, Limited, Ashton-under-Lyne. This engine, which can be clearly seen on the right in Fig. 1, is one of the makers' latest vertical type. The engine is located at right angles to the pump, and is coupled to the horizontal shaft, shown to the left in Fig. 3, through a flexible coupling. The drive from the shaft to the pump is by enclosed single-reduction spur gearing, as shown in the same figure. The engine runs at 330 r.p.m. to 346 r.p.m., and the pump at 46 r.p.m. to 48 r.p.m., the reduction ratio being approximately 7 to 1. The pump plungers have a diameter of 125 mm. ($4\frac{53}{64}$ in.) and the stroke is 24 in. The natural gas on which the engine will operate has a calorific value of 1,000 B.Th.U. per cubic foot, and to reproduce actual running conditions during the test in Messrs. Hayward-Tyler's works, a mixture of town gas and propane was employed, having approximately the same calorific value.

The most interesting feature of the pump is probably the two cylinder bodies, one of which is illustrated in Figs. 7 to 11, opposite. The bodies are machined from billets of 30-ton to 35-ton steel, and not only the cylinders, but all passages and valve ports, were bored out from the solid. The billets were also machined on all outside faces, and the width at the top was reduced by machining from 2 ft. $1\frac{1}{2}$ in. to $10\frac{3}{4}$ in., to a depth of $7\frac{7}{8}$ in., to reduce the weight. All cross-passages were made by boring from one side of the billet, the end at which the tool was inserted being afterwards closed by a plug, screwed and welded into place. The procedure can be readily followed from Figs. 8 and 11. The longitudinal passages, being of much greater length, were bored through, a plug, again screwed and welded, being inserted at each end as shown in the top part of Fig. 7 and in Fig. 9. There is one suction opening, 6 in. in diameter, in the underside of each body at the middle, and this communicates, by means of the cross-passage shown in Fig. 10, with two longitudinal passages, one of which is shown in Fig. 9. There are eight suction valves, four at each end, located in short vertical branches above the horizontal passages, giving 16 suction valves per body. The recesses in which the seatings for the suction valves are located can be seen in Figs. 8 and 9, and from the former figure, it will be seen that the space above each valve communicates by a short horizontal branch with one of the cylinders, there being two cylinders back to back, as shown in Fig. 7. The delivery valves, of which there are four associated with each cylinder, are located in short vertical passages above the cylinders, the recesses for the seatings being shown in Figs. 7 and 8. It will be observed that all the delivery valves discharge into a common longitudinal passage with the outlet port in the middle at the top of the body. Details of the suction and delivery valves are given in Fig. 6, Plate XXII, and it will be observed that they are both of the ordinary mushroom type.

The action of the pump can now be readily followed, bearing in mind that it is of the double-acting duplex type. The two throws of the crankshaft are at 90 deg., and, as shown in Fig. 2, each is coupled by a connecting rod of conventional type to one of the inner crossheads. The outer crossheads are coupled to the inner crossheads by long rods, visible in Figs. 1 and 3. The plungers, as already mentioned are 125 mm. in diameter, while the cylinders are 6 in. in diameter. Each group of four suction or delivery valves is thus in constant communication the one with the other, and simply operates as one valve, four small valves being employed in place of one large valve to give a simpler form of body, lighter and simpler valves, and easier maintenance of the valves. The suction openings below the two bodies are connected by a Tee-pipe to the main suction pipe, and the two delivery openings at the top by a second Tee-pipe to the main delivery pipe. The latter can be clearly seen in Fig. 1, with the suction pipe passing down between the two pump bodies on the left. The suction Tee is also shown in Figs. 2 and 3.

Turning now to the constructional details, it will be seen from Figs. 1, 2 and 3 that the pump frame is built up of three parts, the main bedplate incorporating the main slides, the pump bodies, and a subsidiary bedplate on which the slides for the outer crossheads are formed. These three parts are bolted together. The main bedplate is in two parts, bridged with cast-iron bracing members, one part for each pump body. As will be clear from Fig. 1, each part is provided with a hooded flange at the pump end for bolting to the bodies, while the other ends are formed into housings to take the main crankshaft bearings. A deep extension is cast on at the end remote from the bodies to take the separate countershaft bearings. The castings are of sufficient length to leave ample space for packing the glands. The castings are provided with side facings to take the cross-bracing members, which are machined and bolted to the two parts of the bedplate. The member at the pump end is extra wide, and is machined to fit the corner of the main beds to ensure rigidity and to prevent twisting when the pump is in operation. The crosshead slides, formed in the hooded portions of the bedplate, are of the circular type, as will be clear from the end view of the main crosshead, Fig. 5, Plate XXII. Three oil wells are cast in the lower part of the bed to take the leakage oil from the stuffing boxes, the lubricating oil from the slides, and the lubricating oil from the main crank and connecting-rod bearings, respectively. The main crankshaft bearings, shown in Figs. 14 and 15, are of extra heavy construction to prevent bending. They are of the four-part type of close-grained cast-iron, and are lined with white metal. As shown in Fig. 14, steel adjusting wedges are provided, adjustment being effected by bolts and lock nuts. Three countershaft bearings of the ring type are provided, these bearings having glands to prevent leakage of oil along the countershaft. The correct working centres are secured by means of steel wedges on the bedplate, the bearings being afterwards fitted with steel dowel pins. All the bearing caps are of cast iron and are of extra heavy construction with machined lips over the edges of the main bearing casting to give rigidity, as shown in Fig. 14.

The crankshaft, illustrated in Figs. 12 and 13, is of the built-up type, the arms being shrunk and keyed to the shaft proper. It is of 33-ton to 35-ton mild steel, and is machined all over. The central part of the shaft is increased in diameter to take the spur wheel. The pins are shrunk and keyed in the crank arms. Single-reduction gearing is employed, supplied by Messrs. David Brown and Sons (Hudd), Limited, Huddersfield. It consists of a forged-steel pinion having 29 teeth engaging with a composite spur wheel having 208 teeth. The wheel consists of a solid forged-steel rim secured to a substantial cast-steel centre, and is made in halves with machined joints, the halves being held together by means of turned and fitted bolts. The gearing is designed to transmit 230 brake horse-power continuously, 24 hours a day, at 330 r.p.m. to 346 r.p.m. The working face of the gears is 260 mm. ($10\frac{17}{64}$ in.) wide and the shaft centres are 47·15 in. apart. The gearing is totally enclosed in a sheet-steel casing, visible in Fig. 1. This casing is in halves and is stiffened with angle iron. There is a sliding inspection door on the top half.

The connecting rods are 33-ton to 35-ton mild-steel forgings of unpolished round section. The big-end bearing is of the marine type, lined with hard white metal, and fitted with a mild-steel keep plate. The small ends are fitted with a hard bronze bearing with a cotter and regulating nut and pin. The pressure on the big-end bearing surface does not exceed 683 lb. per square inch, and on the small-end bearing surface, 996 lb. per square inch. The main crossheads, illustrated in Figs. 4 and 5, Plate XXII, are of cast steel with an integral yoke for the side rods. They are fitted with cast-iron shoes top and bottom, and have adjusting studs and lock-nuts, as shown in Fig. 4. The shoes are turned to operate in bored guides. The pressure on the shoes does not exceed 28·4 lb. per square inch on the surfaces. The main crosshead pins are of mild steel, case-hardened and ground, and have a double taper in the body of the crosshead. They are provided with a nut and washer, and are prevented from turning by means of a pin. The outer crossheads, one of which is shown in section in Fig. 2, are formed with an adjustable shoe working in a slide to take the weight of the plunger and cross yoke. The method of attaching the plunger to the crosshead is identical with that employed for the main crossheads. The slide extension is formed with separate wells for the lubricating oil and the crude oil. The pump plungers are hollow, and are made from hard steel having a tensile strength of 44·5 tons to 54·3 tons per square inch, and a Brinell hardness number of 240. The surfaces of the plungers are polished. As shown in Fig. 2, the plungers are secured to the crossheads by a split steel keep ring embracing a collar. The stuffing boxes, which are flanged to the bodies as shown in the

same figure, are of cast steel. Provision is made for not less than 6 in. of packing, and the neck bushes are of hard gunmetal. The glands are of cast steel with hard gunmetal liners, and the outer ends are formed into a shallow stuffing box with a gland and packing to arrest any leakage of crude oil past the main gland, and with provision for drawing off the leakage oil to prevent it mixing with the lubricating oil on the slides. The suction and delivery valves are of stainless steel, with springs and seatings of the same material. The velocity of the liquid through the suction valves does not exceed 1·6 ft. per second, and that through the delivery valves does not exceed 2·8 ft. per second.

Sight-feed lubricators are fitted to all the bearings and working surfaces, and are fed from an overhead tank. All surplus oil drains from the various wells into a second tank located in the foundations, and a small rotary pump is fitted to return the oil from the lower to the upper tank. The rotary pump is chain driven off the end of the countershaft, the casing covering the driving chain being visible on the extreme right in Fig. 1, Plate XXII. The lubricating-oil supply tank can be seen in the same figure, together with some of the pipes leading to the sight-feed lubricators.

BRITISH STANDARD SPECIFICATIONS.

The following specifications of engineering interest have been issued by the British Standards Institution. Copies are obtainable from the Publications Department of the Institution, 28, Victoria-street, London, S.W.1, and, unless otherwise stated, the price is 2*s.* net, or 2*s.* 2*d.* including postage.

Electricians' Rubber Gloves.—As a result of experience gained in working to specification No. 697, for rubber gloves for electrical purposes, in this country and overseas, certain modifications were suggested, and a revised specification has now been published. The original edition was issued in August, 1936, and the principal changes made in the revision have as their object a clarification of the original wording, particularly as regards the interpretation of the mechanical tests. Numerous changes have been made in the appendices describing the methods of test, and in a few instances these changes have necessitated alteration of the limits layed down in the specification.

Trailing Cables for Mining Purposes.—Specification No. 708-1940, relating to trailing cables for mining purposes, constitutes a revision of that issued in September, 1936. The revision includes the addition of a section dealing with drill cables as well as some small modifications to the other sections. Hence the publication now covers (*a*) flexible trailing cables for use with coal cutters and similar equipment; (*b*) pliable armoured trailing cables for use with conveyors, loaders, etc.; and (*c*) a section dealing with drill cables. In all cases, constructional details, particulars of the rubber dielectric, marking, approximate overall diameters and tests are specified.

Engineers' Precision Tools.—Two further specifications have now been issued in the series of Standards for engineers' precision tools, namely, No. 887-1940, for vernier callipers and No. 888-1940, for slip (or block) gauges and their accessories. The specification for vernier callipers does not attempt to impose restrictions in regard to details of design but, like the other specifications in this series, is mainly concerned with prescribing limits of error. It relates to callipers in inch and metric measures in seven standard sizes, the largest of which read up to 48 in. and 1 m. respectively. Six types of verniers are described reading to 0·001 in. and 0·01 mm. The specification gives permissible errors in the readings over the range of each size of calliper, and also prescribes the flatness and straightness of the beam and the flatness and squareness of the measuring jaws. Details are given of the manner in which the graduation shall be engraved, and, in an appendix, some recommendations are made in regard to the suitable dimensions for the cross sections of the beams.

The specification for slip (or block) gauges deals with the parallel-faced type of gauge, first introduced by C. E. Johansson about 40 years ago, and now manufactured in Great Britain. The principal matters dealt with in this specification are the series and sizes of the most frequently used sets, the general dimensions of the gauges, the hardness of the steel and the accuracy of the size. As regards the latter, requirements are laid down for standards of accuracy for three grades of gauges, namely, workshop, inspection, and calibration. The specification also deals with the essential requirements of the accessories commonly used with slip gauges, namely, measuring jaws, scribing and centre points, holders and bases. An appendix gives helpful information on the care and use of slip gauges in the workshop and test room.

TENDERS.

We have received from the Department of Overseas Trade, Great George-street, London, S.W.1, particulars of the undermentioned tenders, the closing dates of which are as stated. Details may be obtained on application to the Department at the above address, quoting the reference numbers given.

Foundry Crucibles, Leather Belts, single and double, and *Hair Belting*, required for trades schools. Ministry of Education, Sharia El Falaki, Cairo, Egypt; May 15. (T. 18,050/40.)

Jaw Rock Crusher, with double toggle solid-steel body, mounted on suitable chassis with steel road wheels. Also *Wheel-Type Tractor*, 30-b.h.p., petrol-paraffin. Union Tender and Supplies Board, Pretoria; May 2. (T. 18,251/40.)

Metal-Clad Switchgear, 11,000-volt, three-phase. The City Council, Brisbane, Australia; May 10. (T.Y. 18,200/40.)

Centrifugal Pumps, electric, eight, to be installed at Avellaneda, Province of Buenos Aires. Argentine National Sanitation Works Department, Buenos Aires; April 30. (T. 18,204/40.)

Weir Measuring Apparatus. The Town Council of Springs, South Africa; May 2. (T. 18,248/40.)

Accumulators, one 25-cell, 30 ampere-hours; one 65-cell, 75 ampere-hours; one 25-cell, 50 ampere-hours; and one 30-cell, 100 ampere-hours. Union Tender and Supplies Board, Pretoria; May 2. (T. 18,253/40.)

Alternator, 75-kVA, 380-volt, 50-cycle, three-phase, to be driven from an existing 100-kW direct-current generator. Union Tender and Supplies Board, Pretoria; May 2. (T. 18,256/40.)

Measuring and Testing Instruments, including insulation and resistance testers. Posts and Telegraphs Department, Melbourne, Australia; May 7. (T. 17,068/40.)

BOOKS RECEIVED.

Transactions of the Institution of Water Engineers. Volume XLIV. 1939. Edited by A. T. Hobbs, Secretary. London: Offices of the Institution, Parliament Mansions, Victoria-street, S.W.1.

Engineering Economics. Works Organisation and Management. Book II. *Works Organisation and Management.* By T. H. Burnham. Fifth edition. London: Sir Isaac Pitman and Sons, Ltd. [Price 10*s.* 6*d.* net.]

The New Zealand Institution of Engineers. Proceedings. 1938-39. Volume XXV. 8-12. The Terrace, Wellington, C.1: Offices of the Institution.

United States War Department. Lake Series No. 9. 1939. *The Ports of Fairport, Ashtabula and Conneaut, Ohio.* Washington: Superintendent of Documents. [Price 1 dol.]

On the Application of the Brunsviga Twin 13z Calculating Machine to Survey Problems. By Dr. L. J. Comrie. Second edition. London: Scientific Computing Service, Ltd., 23, Bedford-square, W.C.1. [Price 5*s.*]

Modern Machine Calculation with the Facit Calculating Machine Model Lx. By H. Sabielny. Translated and revised by Drs. L. J. Comrie and H. O. Hartley. London: Scientific Computing Service, Ltd., 23, Bedford-square, W.C.1. [Price 5*s.*]

Istituto Sperimentale Stradale. Ricerche e Studi. Volume III. 1939. Via Mangiagalli 14, Milan: Istituto Sperimentale Stradale.

Physico-Chemical Methods. By Professors Joseph Reilly and W. N. Rae. In two volumes. London: Methuen and Co., Ltd. [Price 84*s.* the two volumes.]

United States Department of the Interior. Geological Survey. Water-Supply Paper No. 818. *Geology and Water Resources of the Mud Lake Region, Idaho, Including the Island Park Area.* By H. T. Stearns, L. L. Bryan and Lynn Crandall. [Price 75 cents.] Water-Supply Paper No. 828. *Surface Water Supply of the United States*, 1937. Part 8. *Western Gulf of Mexico Basins.* [Price 50 cents.] Water-Supply Paper No. 835. *Surface Water Supply of Hawaii. July* 1, 1936, *to June* 30, 1937. [Price 20 cents.] Washington: Superintendent of Documents.

Third Annual Proceedings of The Railway Fuel and Traveling Engineers' Association. Hotel Sherman, Chicago, Ill. October 17th to 19th, 1939. Chicago: The Railway Fuel and Traveling Engineers' Association.

The Association of Engineering and Shipbuilding Draughtsmen. Electro-Hydraulic Applications. By H. Gibbon. 1 Links-road, Epsom, Surrey: The Draughtsman Publishing Company, Limited. [Price 2*s.* net.]

Ingeniørvidenskabelige Skifter. 1939. No. 4. *The Acoustic Air-Jet Generator.* By Jul. Hartmann. Vimmelskaftet 32, Copenhagen K.: G. E. C. Gad.

The Water Engineer's Handbook and Directory, 1940. *The Water Engineer's Vade Mecum.* London: "Water and Water Engineering" Offices, 30 and 31, Furnival-street, Holborn, E.C.4. [Price 8*s.* 6*d.*]

PERSONAL.

Dr. E. H. Rayner retired from the post of Superintendent of the Electricity Department, National Physical Laboratory, Teddington, Middlesex, on March 31, having attained the normal age limit. He has been succeeded by Mr. R. S. J. Spilsbury, formerly principal scientific officer in the Department.

Mr. E. W. Spalding, M.C., Wh.Ex., A.M.I.Mech.E., who was apprenticed to Messrs. Ruston and Hornsby, Limited, Lincoln, in 1897, and has spent all his subsequent career with the firm, has now been appointed general sales manager of the Company.

Messrs. William Steward and Company, Limited, electrical contractors, have removed from 67, Osnaburgh-street, to more extensive premises at 154, Albany-street, London, N.W.1.

Mr. Arthur Everett has been elected vice-chairman of the Tyne Improvement Commission, Newcastle-upon-Tyne.

Mr. L. C. Timms, lecturer in mining at the Technical College, Doncaster, has recently been appointed senior investigator to the Lancashire and Cheshire Safety in Mines Research Committee.

Mr. W. G. Suffield has been appointed a director of Messrs. Dewrance and Company, Limited, Great Dover-street, London, S.E.1, and will continue to control sales, as formerly. Mr. A. Denison Ross, M.A., A.M.I.Mech.E., has been appointed technical assistant to the management.

Mr. F. S. Naylor, chief electrical engineer of Messrs. Thos. Firth and John Brown, Limited, Sheffield, has been appointed borough electrical engineer of Southwark in succession to Mr. D. M. Kinghorn.

Mr. B. Handley, city electrical engineer, Portsmouth, has been nominated President of the Incorporated Municipal Electrical Association for 1940-41.

Sir James Swinburne, Bart., F.R.S., has become president of the Association of "Old Cromptonians" in succession to the late Colonel R. E. Crompton. Sir James was technical manager of Messrs. Crompton and Company, Limited, from 1885 to 1889.

Lord Dudley Gordon was elected President of the Federation of British Industries, 21, Tothill-street, London, S.W.1, at the annual general meeting held on April 10. Mr. Peter Bennett, who is now Director-General of the production of tanks and mechanical transport at the Ministry of Supply, retired after having held office as President of the Federation for two years.

Mr. J. E. Nelson, M.I.E.E., chief engineer of the Mersey Power Company, Limited, has been elected chairman of the Mersey and North Wales Centre of the Institution of Electrical Engineers for the 1940-41 session. Mr. E. G. Taylor and Mr. H. Pryce-Jones were elected vice-chairmen.

Mr. F. S. Coates, district engineer at Alnwick for the North Eastern Electric Supply Company, Limited, has been appointed district manager of the Yorkshire Electric Power Company.

NOTES FROM THE SOUTH-WEST.

Cardiff, Wednesday.

The Welsh Coal Trade.—The need for increasing the district's output of coal to enable shippers to take fuller advantage of the increased demand circulating on the steam-coal market was again attracting interest last week. The demand on both home and export account was actively maintained, but few new orders could be entertained, with the result that the general tone was strong. The decision of the Government to appoint a committee to find ways and means of increasing the output of coal was warmly welcomed in the area. Lord Portal, who was nominated to preside over the committee, visited Cardiff during the week to discuss the matter with local interests. Duff coals were scarce and, with stem lists for these kinds well filled over several months ahead, the tone was very strong. Sized and large qualities were not easy to secure for shipment over the next few months, while offers of smalls were limited. The demand for cokes was well sustained but the tone was firm. Patent fuel was in good demand.

The Iron and Steel Trade.—Active conditions were maintained in the iron and steel and allied trades of South Wales and Monmouthshire. Most works were engaged almost to full capacity and, with order books well filled, the general tone was very firm.

Licences of Surrendered Motor Vehicles.—Following representations by the Commercial Motor Users' Association, the Chancellor of the Exchequer has stated that licensing authorities have been instructed that in cases in which the War Office takes a motor vehicle out of the owner's control and the Road-Fund licence is surrendered, a rebate of duty may be obtained on the same terms as would apply in the case of a requisitioned vehicle.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Sheffield manufacturers are doing their best to develop export trade, and the Board of Trade's request that local firms should form export groups has been readily acceded to. The products covered by such groups are machine knives, files, scythes, sickles, hooks, hay knives, sheep shears, and saws of all types. The formation of other groups is under consideration. The latest report of the Sheffield Chamber of Commerce shows that export inquiries are on the increase. Ordinary commercial business on inland account is more brisk, and Sheffield works are receiving their share of the orders in circulation. The Sheffield Corporation Electricity Department is to place contracts for transformers and switchgear, and the Department has also accepted a tender for the supply and erection of switchgear. Satisfactory conditions prevail in the raw and semi-finished steel-making branches. Users of basic and acid materials are having little difficulty in obtaining supplies. Steel makers report that supplies of pig iron, hematites, and alloys have been well maintained. Rod and bar mills are operating to capacity. Structural steel is in strong demand and cold-rolled strip is in active request. Widespread activity marks the heavy machinery and engineering branches. Hollow forgings and boiler drums of record size and weight are being produced. Makers of shipbuilding requisites are busy with the production of steel forgings and castings, machinery, and deck furnishings. During the past few weeks the output of agricultural steel, machinery, and parts has improved considerably, the gross turnover being the highest for many years.

South Yorkshire Coal Trade.—There is a brisk demand for coal for industrial purposes. Steel and engineering, works are buying larger tonnages, and are laying in stocks. Electricity works are also in the market for small coal. House coal requirements are higher than the seasonal average, and a steady business is being done in most types of coke.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—The events of the past week have been of interest to the Scottish steel trade. There will be no reduction in the amount of steel materials exported from this area. Under the present conditions, we may receive a larger tonnage of semi-manufactured steel from Belgium and Luxembourg which will be very acceptable. The local steelworks are extremely busy and the demand is as great as ever with the result that plant is being kept running at full capacity. The quantity of black-steel sheets on order is very heavy and production is being maintained at a high level. Structural sections are also in steady demand. With fairly good deliveries of scrap steel during the past week or two, the raw material position has improved. The following are present quotations:—Boiler plates, 13*l.* 8*s.* per ton; ship plates, 12*l.* 10*s.* 6*d.* per ton; sections, 12*l.* 8*s.* per ton; medium plates, under $\frac{5}{16}$ in. thick, weighing 6 lb. or more per square foot, 14*l.* per ton, and weighing under 6 lb. but not less than 4·81 lb. per square foot, 14*l.* 10*s.* per ton; black-steel sheets, No. 24 gauge, in 4-ton lots, 17*l.* 10*s.* per ton; and galvanised corrugated sheets, No. 24 gauge, in 4-ton lots, 20*l.* per ton, all delivered at Glasgow stations.

Malleable-Iron Trade.—A steady demand for bar iron is general and the West of Scotland works are well employed at present as the supply of raw material is satisfactory. The re-rollers of steel bars are extremely busy and are experiencing a steady pressure for the delivery of orders now on hand. The supply of semies has been very good recently and the re-rollers are expecting increased tonnages from Belgium during the next few weeks. The current prices are as follows:—Crown bars, 12*l.* 17*s.* 6*d.* per ton; No. 3 bars, 12*l.* 10*s.* per ton; No. 4 bars, 12*l.* 15*s.* per ton; and re-rolled steel bars (tested), in 4-ton lots, 14*l.* 3*s.* per ton, all for home delivery.

Scottish Pig-Iron Trade.—No change is reported in the state of the Scottish pig-iron trade. Stocks of ore are ample for the present and the immediate future. Trade circles consider that supplies will remain ample. To-day's market quotations are as follows:—Hematite, 6*l.* 7*s.* 6*d.* per ton, and basic iron, 5*l.* 4*s.* 6*d.* per ton, both delivered at the steelworks; foundry iron, No. 1, 5*l.* 15*s.* per ton, and No. 3, 5*l.* 12*s.* 6*d.* per ton, both on trucks at makers' yards.

THE MEASUREMENTS OF HEEL AND TRIM: ADDENDUM.—We are asked by Mr. T. U. Taylor, A.M.I.N.A., author of the paper on "The Measurement of Heel and Trim," which was reprinted on page 399, *ante*, to state that the apparatus described in the paper is the subject of an application for Letters Patent. This fact was mentioned in the paper, but was omitted in our abridgment.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

General Situation.—Efforts to increase the iron and steel production still further have met with some success, but the unprecedented output is absorbed as soon as it becomes available. Ordinary commercial inquiries are on a considerable scale, but buyers are experiencing some difficulty in placing orders for material for general industrial requirements.

Cleveland Iron Trade.—There is no shortage of foundry iron, but the local output is intermittent, and of a lower standard than the usual brands, the production of which has been suspended for some time. Supplies of Midland iron, however, continue to arrive regularly on a scale that meets customers' requirements. Second hands have control of only moderate lots of Cleveland pig or foundry iron from other producing areas. The fixed prices of local products remain on the basis of No. 3 quality of Cleveland at 111*s.*, delivered within the Tees-side zone.

Hematite.—Makers of East Coast hematite are turning out heavy tonnages, but have little iron stored. The requirements of makers' own consuming departments are heavy and increasing, while buyers' contracts leave little tonnage available for the market. Merchants' holdings are light. Enlargement of the output may soon be necessary to cope with the increasing demand. Producers are expecting to be able to deal with actual requirements, and inactive plant could be readily put into operation should the need arise. Stabilised quotations remain at the equivalent of No. 1 grade of hematite at 127*s.* 6*d.*, delivered to North of England firms.

Basic Iron.—With no basic iron on sale, the quotation of 104*s.* 6*d.* is nominal. Steelworks owned by makers continue to absorb the whole production of the basic furnaces.

Foreign Ore.—Satisfactory accounts are given of conditions in the foreign-ore trade. Consumers have good working stocks and imports promise to continue on a substantial scale.

Blast-Furnace Coke.—Business in Durham blast-furnace coke matures slowly since local users have little occasion to buy and holders are extensively sold. Regular deliveries serve to meet the requirements of Tees-side consumers. Market values are very firm at the level of good medium qualities at 31*s.* 8*d.* at the ovens.

Manufactured Iron and Steel.—The production of semi-finished iron and steel is well maintained and imports of Continental semies are substantial, so that re-rollers are receiving sufficient material to enable them to keep the mills fully employed. In the finished industries manufactured-iron firms have as much work on hand as they can handle, and producers of steel are maintaining outputs at record levels.

Scrap.—The situation as regards scrap is little changed, but the scarcity of one or two descriptions of material is not so acute as formerly.

NATIONAL PHYSICAL LABORATORY.—A new Department of Light has been formed at the National Physical Laboratory, Teddington, Middlesex, to comprise the former Optics Division of the Physics Department and the Photometry Division of the Electricity Department. Mr. T. Smith, F.R.S., has been appointed Superintendent of the new Department as from April 1.

GEAR-MANUFACTURERS' EXPORT GROUP.—At a meeting, held at the Hotel Victoria, London, on April 10, under the auspices of the Export Council, a Gear-Manufacturers' Export Group was formed and a chairman, secretary and committee elected. In order to ensure that all gear manufacturers interested in work for export have an opportunity of expressing their views and to confirm the appointments and elections made at the first general meeting, a further meeting is convened for Friday, May 3, at 2.45 p.m., at the Hotel Victoria, Northumberland-avenue, London, W.C.2. All firms interested are invited to be present, and to communicate with Mr. J. C. R. Birney, Room 632, Bush House, London, W.C.2.

THE INSTITUTE OF METALS.—As announced on page 286 *ante*, a general meeting of the Institute of Metals will be held on Wednesday, May 8, at 2 p.m., at the Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, when three papers will be presented for discussion, namely, "The Influence of Alloying Elements on the Crystallisation of Copper. Part II.—Large Additions and the Part Played by the Constitution," by Dr. L. Northcott; "The Structural Changes in Copper Effected by Cold Rolling and Annealing," by Dr. M. Cook and Dr. T. Ll. Richards; and "The Ageing of High-Purity 4 per cent. Copper-Aluminium Alloy," by Dr. M. L. V. Gayler and Mr. R. Parkhouse. The meeting will be followed in the evening, at 7 p.m., by the thirtieth annual May Lecture. This, which will deal with "The Cyclotron and Its Applications," will be delivered by Professor J. D. Cockcroft, F.R.S.

NOTICES OF MEETINGS.

IT is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

INSTITUTION OF MECHANICAL ENGINEERS.—To-night, 6 p.m., Storey's-gate, Westminster, S.W.1. General Meeting. "The Problems of the Singing Propeller," by Professor W. Kerr, Dr. J. F. Shannon and Dr. R. N. Arnold. *Internal Combustion Engine Group:* Friday, April 26, 6 p.m., Storey's-gate, Westminster, S.W.1. Extra General Meeting. "Fuel Injection in Oil Engines in Relation to Combustion," by Mr. G. W. A. Green.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—To-night, 6 p.m., The Mining Institute, Newcastle-upon-Tyne. (i) "Modern Joiner Work and Woodworking Veneers," by Mr. A. C. Meredith. (ii) "Decorative Veneers," by Mr. L. C. W. Jenkins. *Student Section:* Wednesday, April 24, 6.45 p.m., Bolbec Hall, Newcastle-upon-Tyne. "Hatchways," by Mr. J. B. Davies.

ROYAL AERONAUTICAL SOCIETY.—To-night, 6.30 p.m., The Institution of Electrical Engineers, Savoy-place, Victoria-embankment, W.C.2. Lecture: "Some Aspects of the Aerial Warfare in the German-Polish Campaign," by Mr. S. Rogalski.

JUNIOR INSTITUTION OF ENGINEERS.—*Midland Section:* Saturday, April 20, 2.30 p.m., The James Watt Memorial Institute, Birmingham. "Electrical Distribution," by Mr. D. Birch. *Institution:* Friday, April 26, 6.30 p.m., 39, Victoria-street, Westminster, S.W.1. Informal Meeting. Lecture: "The Construction of High-Level Huts in the Alps," by Mr. R. P. Mears.

INSTITUTION OF PRODUCTION ENGINEERS.—*Sheffield Section:* Monday, April 22, 7 p.m., The Grand Hotel, Sheffield. Lecture: "The Manufacture and Uses of Carbides," by Mr. H. Burdon. *London Section:* Tuesday, April 23, 7.30 p.m., The Mostyn Hotel, Portman-square, W.1. Lecture: "Impressions of American Methods," by Mr. G. W. Clarke.

INSTITUTION OF CHEMICAL ENGINEERS.—Tuesday, April 23, 5.15 p.m., The Geological Society's Rooms, Burlington House, Piccadilly, W.1. "A Review of Certain Unit Processes," by Mr. J. C. Farrant.

INSTITUTION OF CIVIL ENGINEERS.—Tuesday, April 23, 5.30 p.m., Great George-street, Westminster, S.W.1. "Remodelling of the Asyût Barrage, Egypt," by Mr. J. E. Bostock.

INSTITUTION OF ELECTRICAL ENGINEERS.—*Wireless Section:* Tuesday, April 23, 6 p.m., Savoy-place, Victoria-embankment, W.C.2. Informal Meeting. Discussion on "War-Time Standardisation," to be opened by Mr. P. R. Coursey. *Scottish Centre:* Tuesday, April 23, 6.15 p.m., The Royal Technical College, George-street, Glasgow, C.1. Annual General Meeting. "The Trolleybus," by Mr. G. F. Sinclair. *Institution:* Thursday, April 25, 6 p.m., Savoy-place, Victoria-embankment, W.C.2. Ordinary Meeting. Thirty-First Kelvin Lecture: "Thermodynamics and the Coldest Temperatures," by Dr. C. G. Darwin.

SHEFFIELD METALLURGICAL ASSOCIATION.—Tuesday, April 23, 6.30 p.m., 198, West-street, Sheffield, 1. "Quenching," by Mr. G. Parkin.

INSTITUTION OF AUTOMOBILE ENGINEERS.—*Birmingham Centre:* Tuesday, April 23, 7 p.m., The James Watt Memorial Institute, Birmingham. General Meeting. "Some Problems We Meet," by Mr. L. H. Dawtrey.

INSTITUTION OF STRUCTURAL ENGINEERS.—*Yorkshire Branch:* Tuesday, April 23, 7 p.m., The Hotel Metropole, Leeds. Ordinary Meeting. "New Developments in Pre-Stressed Concrete Construction," by Mr. T. J. Gueritte.

NEWCOMEN SOCIETY.—Wednesday, April 24, 2.30 p.m., The Science Museum, South Kensington, S.W.7. Ordinary General Meeting. (i) "The Earliest Industrial Use of Coal," by Dr. T. T. Read. (ii) "A Picardy Post Mill, 1630," by Mr. and Mrs. Rex Wailes.

INSTITUTE OF FUEL.—Thursday, April 25, 6 p.m., The Connaught Rooms, Great Queen-street, Kingsway, W.C.2. "Some Food for Thought in Steam Plant Design," by Mr. J. N. Dundas Heenan.

ROYAL INSTITUTION.—Friday, April 26, 9 p.m., 21, Albemarle-street, W.1. "Geophysical Study of Submarine Geology," by Dr. E. C. Bullard.

ROYAL SANITARY INSTITUTE.—Saturday, April 27, 10 a.m., The City Museum, Leeds. Discussions: (i) "The Garchey System of Refuse Disposal," to be opened by Professor J. J. Jervis. (ii) "Modern Flat Building," to be opened by Mr. R. A. H. Livett.

INSTITUTION OF CHEMICAL ENGINEERS.—The Council of the Institution of Chemical Engineers has awarded the Osborne Reynolds Medal to Dr. A. J. V. Underwood, the Moulton Medal to Messrs. G. W. Hewson and R. Ll. Rees, and the Junior Moulton Medal to Dr. A. K. G. Thomas.

ALL-WELDED ROAD BRIDGE AT CLAYHITHE, CAMBRIDGESHIRE.

MR. A. E. PEAKE, COUNTY SURVEYOR.

(*For Description, see Page* 409).

Fig. 5. INSIDE ELEVATION OF MAIN FRAME

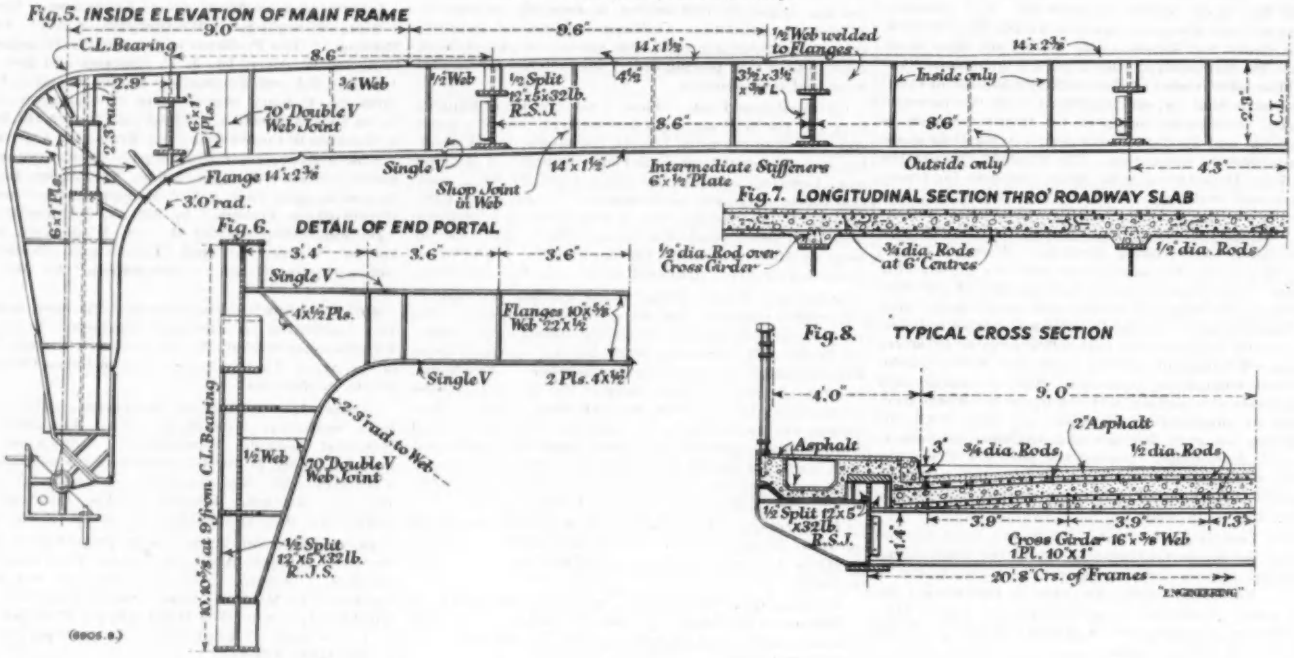


Fig. 6. DETAIL OF END PORTAL

Fig. 7. LONGITUDINAL SECTION THRO' ROADWAY SLAB

Fig. 8. TYPICAL CROSS SECTION

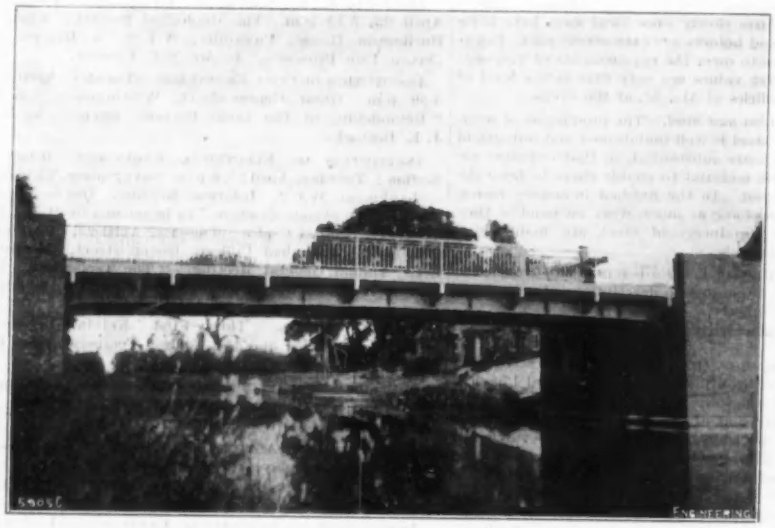


Fig. 9. General View of Bridge.

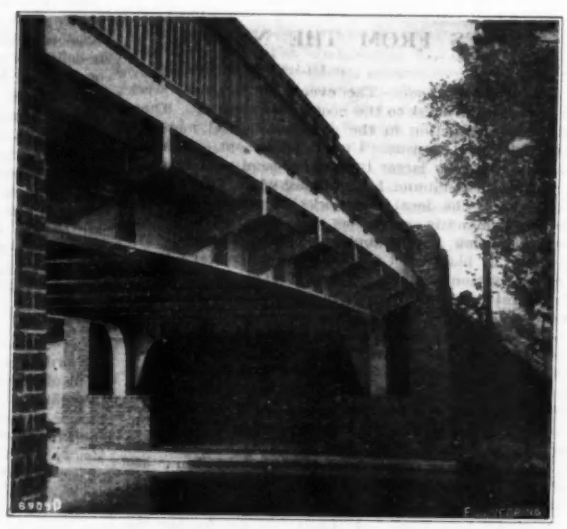


Fig. 10. View Showing End Portal Frame.

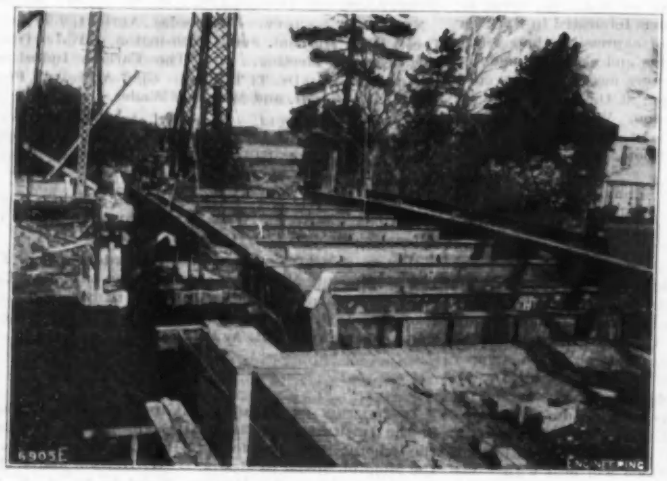


Fig. 11. Cross Girders in Position.

Fig. 12. Attachment of Cross Girders to Main Frame.

DUPLEX DOUBLE-ACTING HORIZONTAL OIL PUMP.

MESSRS. HAYWARD-TYLER AND COMPANY, LIMITED, ENGINEERS, LUTON.

(*For Description, see Page* 411.)

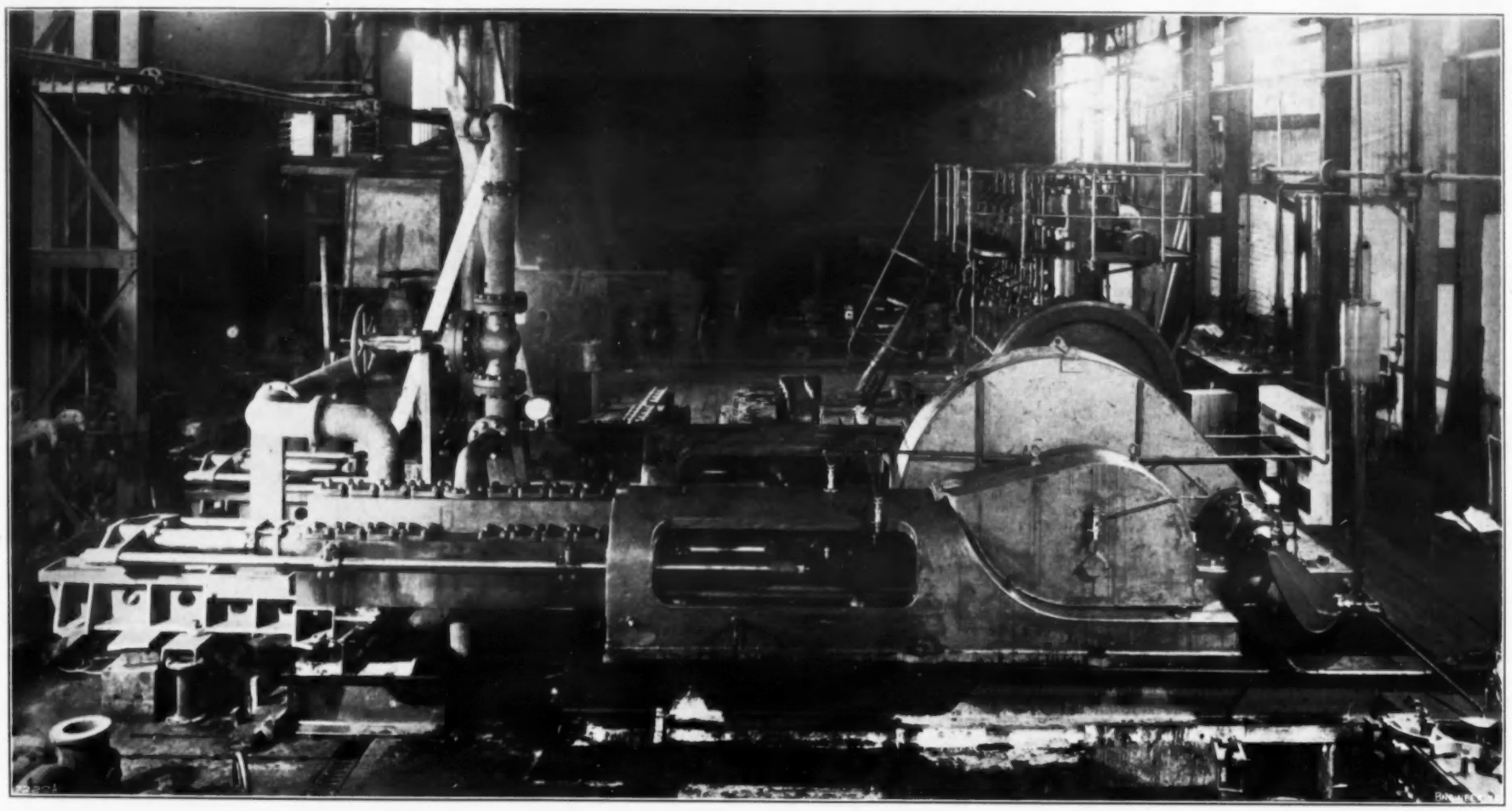
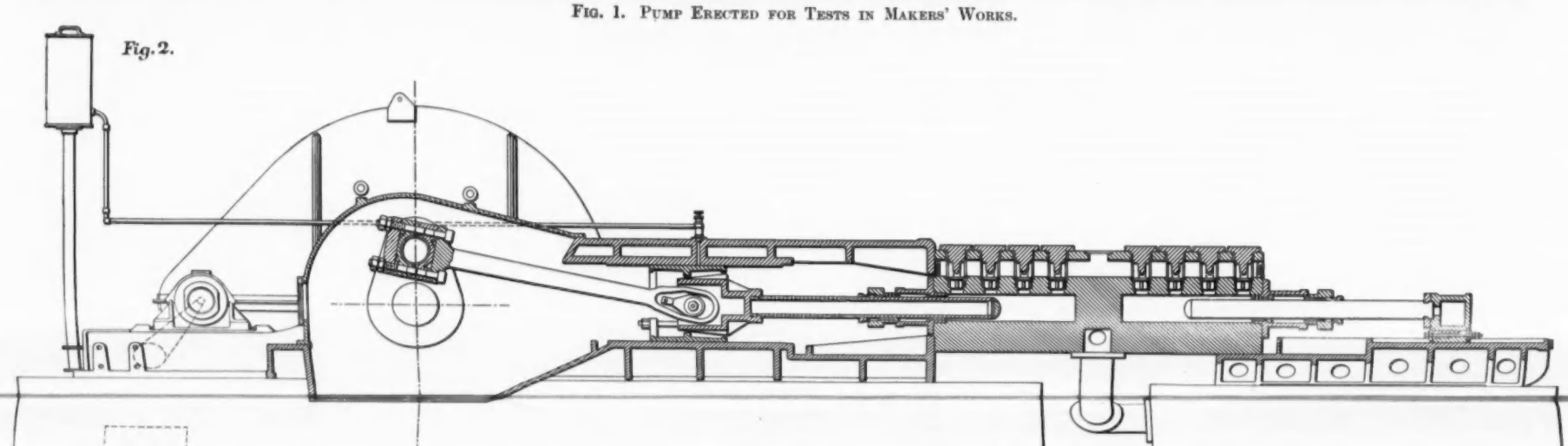


Fig. 1. Pump Erected for Tests in Makers' Works.

Fig. 2.



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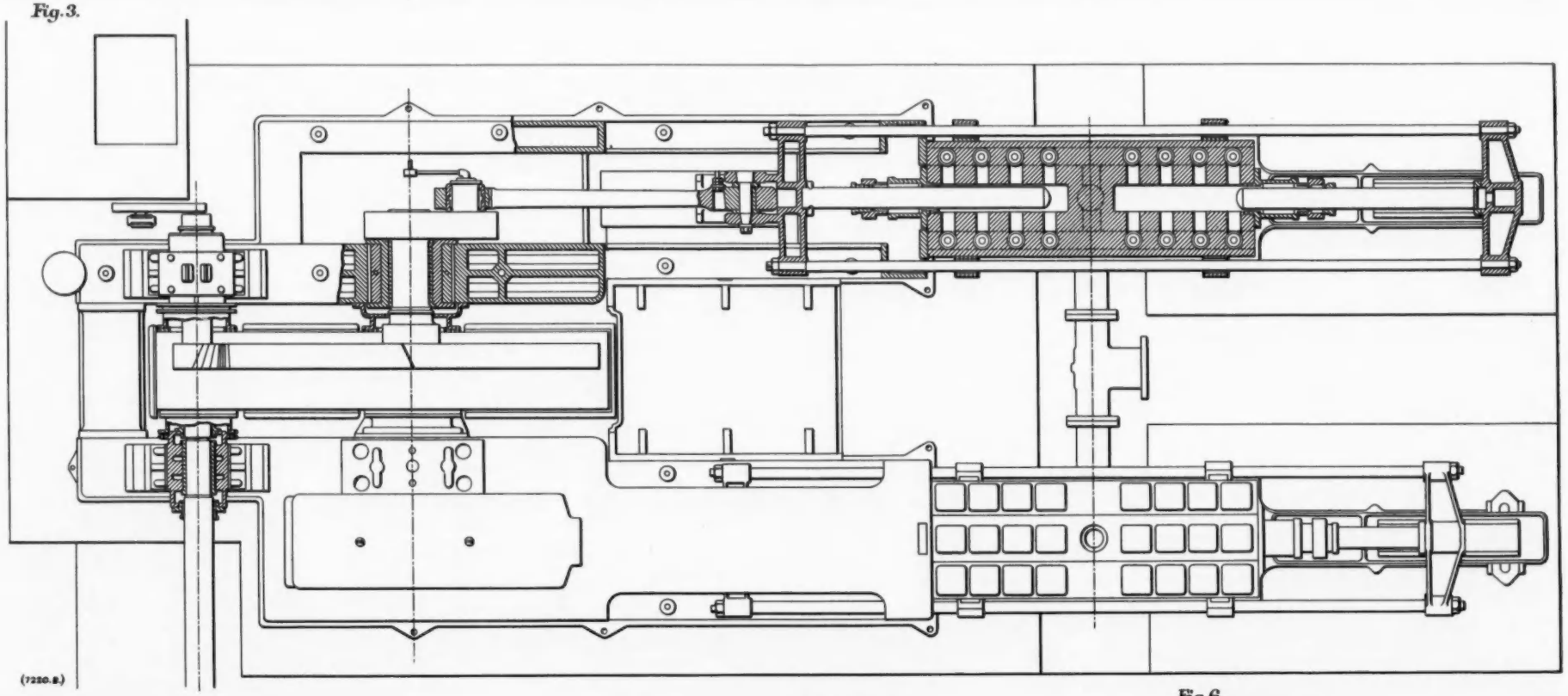

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Fig. 4.

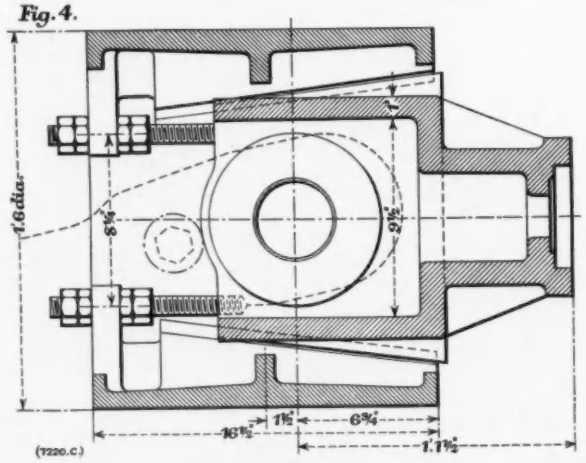

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Fig. 5.

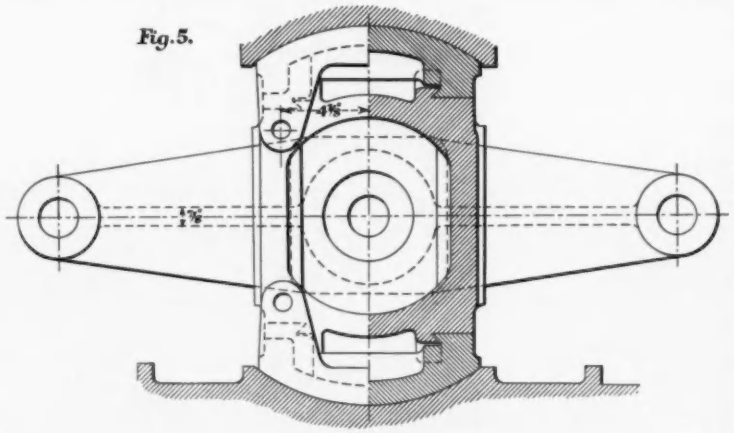
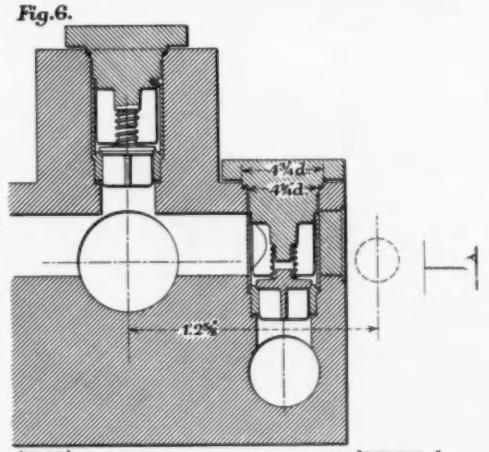


Fig. 6.



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"ENGINEERING"

ENGINEERING.

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TIME FOR RECEIPT OF ADVERTISEMENTS.

Classified advertisements intended for insertion in the current week's issue must be delivered not later than first post on Wednesday. Alterations to standing advertisements must be received at least 10 days previous to the day of Publication. Passed proofs must be in our hands by Saturday morning, otherwise they will be taken as correct. The proprietors will not hold themselves responsible for blocks left in their possession for more than two years.

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TEMPORARY ADDRESS.

For the duration of hostilities, the Editorial and Publishing business of this Journal is being conducted from 18 and 20, Compton Road, Hayes, Middlesex. The Telephone Number of the Editorial Department is Hayes 1730, and that of the Publishing Department, Hayes 1723. The Bedford Street Offices are open on Fridays only, between 10 a.m. and 5 p.m., for the distribution of the current issue and for retail sales.

CONTENTS.

	PAGE
The Juliana Ship Canal, Holland (*Illus.*)	403
Literature.—The Medieval Fenland. The Draining of the Fens. Timber—Its Properties, Pests and Preservation	404
Some Effects of Short-Circuits on Three-Phase Transmission Lines (*Illus.*)	405
Women and Munition Work	407
All-Welded Road Bridge at Clayhithe (*Illus.*)	409
Duplex Double-Acting Horizontal Oil Pump (*Illus.*)	411
British Standard Specifications	412
Tenders	412
Books Received	412
Personal	412
Notes from the South-West	412
Notes from South Yorkshire	413
Notes from the North	413
Notes from Cleveland and the Northern Counties	413
Notices of Meetings	413
The Roads in War	415
The Design of Low-Voltage Switchgear	416
Notes	417
The Loss of H.M.S. "Thetis"	417
The Late Sir George Buchanan, K.C.I.E.	419
The Late Sir William Meade-King	419
Fifty Years of Marine Engineering	420
Electricity as Applied to Metallurgy	421
Transportable Compressor Plant (*Illus.*)	421
Labour Notes	422
Forty Years' Development in Mechanical Engineering Plant for Power Stations (*Illus.*)	423
Electrolytic Corrosion of Ship Structures (*Illus.*)	425
Doall Height and Depth Gauge (*Illus.*)	427
Determination of Tellurium in Tin-Rich Alloys	427
Catalogues	427
"ENGINEERING" Patent Record (*Illus.*)	428

One Two-Page Plate.—DUPLEX DOUBLE-ACTING HORIZONTAL OIL PUMP.

ENGINEERING

FRIDAY, APRIL 19, 1940.

VOL. 149. No. 3875.

THE ROADS IN WAR.

ALTHOUGH a state of war involves many serious troubles, it does serve to emphasise what is essential and what is non-essential in the life of the people. A striking instance is afforded by the present position regarding the roads of this country. In the latest Report on the Administration of the Road Fund,* covering the year ending March 31, 1939, it is stated that the proposals submitted up to the end of the year in connection with the Five-Year Plan envisaged an expenditure of 130,834,000*l.*, and at that date, schemes estimated to cost 106,140,000*l.* had been accepted in principle for grant purposes, the Road Fund contribution being approximately 62,407,000*l.* It may be recalled, in passing, that even those sums were regarded as hopelessly inadequate in some quarters, individuals going so far as to state that our antiquated road system bid fair to throttle our industrial prosperity, and putting forward schemes of new construction involving a truly colossal expenditure. Whatever justification there may have been for these views in peace time, hardly a dissentient voice was raised at the announcement, made soon after the outbreak of war, that road work was to be limited to the completion of essential schemes already in hand, and that no new work of a major character was to be undertaken. Although there appears to have been some relaxation of this attitude on the part of the Government subsequently, road work at the present time is largely at a standstill. It may, therefore, be assumed that the Government, no doubt after consultation with their military advisers, regard the present road system as adequate to meet any likely emergency.

It is, of course, necessary to make a distinction between road requirements in war and peace, particularly if, as in the present case, total war is meant. We take it that this phrase, which was recently made use of by the Minister of Supply, means the direction of every activity of the people to the achievement of victory. From this point of view, amenities, which played a large part in road construction in pre-war years, have no place, and the question of road construction and maintenance simply resolves itself into one of the best use of money and man power. It is, perhaps, hardly necessary to point out that this country is in a unique position among the combatants in the present war in virtue of its island position, which, apart from the question of air attack, renders the internal lines of communication practically immune from the possibility of destruction by the enemy. Contrary to earlier expectations, when it was believed that Germany would take advantage of her boasted overwhelming superiority in air strength to attempt to destroy road and rail communications in this country, it now appears that traffic movements are unlikely to be interrupted to the extent originally anticipated, and the authorities have merely to consider whether the road system, in combination with the railways, will be adequate when subjected to such damage as comes within the bounds of probability. It may be assumed from Government pronouncements that an affirmative answer can be given to this question, and that they regard the existing roads, with the railways, as sufficient to fulfil the manifold requirements of war-time transport satisfactorily. The situation on the roads has, of course, been greatly eased by the reduction in private car movements, and although difficulties have arisen owing to exceptionally severe weather conditions, transport facilities have, as a whole, proved adequate in the first seven months of war.

The Report on the Administration of the Road Fund, which we have already mentioned, may appear to be rather of academic interest in view of the fact that the majority of the schemes to which it refers have been suspended. That this suspension will be of only a temporary nature, however, is suggested by the relatively small reduction in the estimated road expenditure for 1940-1941, amounting to only 7,611,000*l.*, and apart from this, it is permissible to take the longer view, and to regard the present time as a suitable one in which to review the projects in hand, and which will probably be resumed in their entirety after the termination of the war.

Apart from proposals emanating from private individuals and road organisations not associated with the Government, two major proposals have been put forward in the last five years for bringing the roads of this country into line with modern conceptions. The first of these, the Government's Five-Year Plan, was specific as regards the money to be expended, but vague as to the scope of the work to be undertaken; while the second, the Bressey Report, outlined a scheme of improvements in considerable detail, but was nebulous on the question of finance. The Five-Year Plan was inaugurated in 1935, and in announcing its introduction, the then Minister of Transport, Mr. Hore-Belisha, explained that its object was to improve the existing roads by the elimination of weak bridges, the removal of blind corners, the provision of dual carriageways, and similar measures. Local authorities were to be invited to submit proposals for a programme of improvements which they proposed to undertake over the full five-year period, and the Minister stated that he would await these proposals before determining the financial limits of the plan. At a later date, it was announced in Parliament that 100,000,000*l.* had been allocated for the purpose of implementing the scheme. It should be borne in mind in connection with this figure that road-fund grants normally cover only a percentage of the total cost of the work to which they are applied, so that the actual sum it was proposed to spend was greatly in excess of the figure given. For reasons which need now not be discussed, there has been considerable delay in implementing the plan, and instead of the work nearing completion at the end of March, 1939, as originally intended, it is stated in the report on the Road Fund that at that date, as already mentioned, schemes estimated to cost 106,140,000*l.* had been accepted in principle for grant purposes, the Road Fund contribution being approximately 62,407,000*l.*

As regards the Bressey Report, issued in May,

* H.M. Stationery Office. Price 1*s.* 0*d.* net.

1938, it may be recalled that this report was divided into two parts, the first part dealing with roads in the London area, and the second with new routes radiating to towns as far distant as Grantham. It was suggested that these radial roads should be entirely new, and that they should be devoted exclusively to motor traffic on the lines of the Autobahnen in Germany. In commenting on the report at the time, we expressed the opinion that the cost of the scheme would be quite beyond any conceivable source that could be earmarked for such a purpose, and that its chief value lay in its usefulness as a guide to the directions in which new work could be initiated to the greatest advantage, and as a warning against a continuance of the haphazard development of the past. Although little has since been heard of the plan, we believe that the work of Sir Charles Bressey and his assistants has by no means been wasted. the recommendations embodied in the report having been given careful consideration when new road work in the Greater London area has been planned or undertaken. Nothing has, however, been done to implement the views contained in the Bressey Report on new trunk roads, neither is there any suggestion in the Road-Fund Report that the construction of such roads is contemplated. It has already been mentioned that only a relatively small reduction has been made in the estimated road expenditure for 1940-41, and it therefore appears that the Ministry of Transport take the view that it will soon be possible to resume road work on a considerable scale. While some may consider that the Ministry are erring on the side of optimism in this respect, it is certainly desirable that the road system as it stands at present should not be allowed to depreciate to any serious extent, and this will involve a considerable amount of work annually. On the other hand, the enormous strain imposed on the financial resources of the country by a major war, in conjunction with the unprecedented demand on man power, will certainly preclude the inauguration of schemes for the construction of entirely new trunk roads before the conclusion of peace. It would be a good thing, however, if the enforced breathing space could be utilised to clarify the position with regard to new trunk roads, so that when work on a large scale can be resumed, it will be on the basis of a clear-cut programme. The two major issues on which pardonable confusion exists in the minds of the public are to what extent new trunk roads are really necessary, and whether such roads should be of the type exclusively devoted to motor traffic, or of the general-purpose variety to which we are already accustomed in this country.

It appears to be the view of the Ministry of Transport that, in general, it is preferable to modernise existing roads rather than undertake entirely new construction, but this view is in complete variance with that of many independent road authorities. While this is, perhaps, hardly the time to discuss the merits and demerits of roads exclusively devoted to motor traffic, it may be pointed out that such roads would be much more costly to construct in this country than in Germany, where they have reached their greatest development. In the latter country, little disguise has been made of the fact that the Autobahnen have been constructed primarily to ensure the rapid movement of military forces, and it still remains to be shown whether this will prove a sound policy. These roads are undoubtedly vulnerable to air attack, to which they have not been subjected up to the present. Perhaps the most noteworthy feature in connection with the German roads is that the average speed of the traffic using them is considerably lower than might have been anticipated, and is, in fact, very little higher than that attained on some of our own main trunk roads. From this point of view, the policy of the Ministry of Transport in showing a preference for modernising existing roads would appear to be justified. It therefore appears that a clarification of the position is eminently desirable, and while such a step would probably be quite impracticable in war time, a strong case could be made out for the appointment, on the conclusion of peace, of an authority to prepare a report on the lines of that issued by Sir Charles Bressey, but to cover the whole country.

THE DESIGN OF LOW-VOLTAGE SWITCHGEAR.

The design of electrical switchgear has virtually ceased to be empirical and is becoming more and more an exact process. It is now possible to manufacture equipment the performance of which can be guaranteed under normal and short-circuit conditions; and, although there are still many problems awaiting solution, the user can be certain that plant constructed and tested in accordance with the latest British Standard specifications will do all that is reasonably required of it. To some extent, at least, this progress can be ascribed to the establishment of the Grid, though probably it was in any event a matter of time, as the use of electricity for all purposes became more widespread; but the nation-wide inter-connection of public generating stations, with the consequent increase in the amounts of energy to be handled, and the need of preserving continuity of supply, has rendered more difficult the task of the switchgear which is necessary for control purposes, and, as a natural corollary, has made the work of its designers more exacting. As is well-known, the result has been the erection of a number of testing stations which have not only enabled differing types of product to be proved, and thus improved, but have increased our knowledge of what happens when circuit-breaker contacts open and close, and when, during a period to be measured in small fractions of a second, interesting phenomena occur. The activities of these stations have been of great value, and as the data accumulated has been applied, so has the efficiency of the product which it is their duty to investigate been increased.

To begin with, this work was confined to the extra high-voltage equipment, such as naturally finds its place in generating stations and main sub-stations. More recently, however, the investigations in switchgear testing stations have been extended to lower voltage products, which, in the aggregate, represent the greater part of the equipment in use. That this should have been the case is only natural, since there are obvious reasons, both economical and technical, why the performance of such apparatus should be accurately determined. Moreover, as pointed out in the paper on "Oil-less Metal-Clad Switchgear for Medium-Voltage Alternating-Current Circuits up to 660 Volts, Three-Phase," which was read before the Institution of Electrical Engineers by Messrs. H. E. Cox and L. Drucquer, on Thursday, March 7, such apparatus may provide the designer with an even more difficult problem than does its more imposing and higher pressure counterpart. For, though the results when low-voltage equipment fails are relatively less spectacular and the consequent interruptions of supply, damage and injury to personnel more limited, the short-circuit currents that have to be dealt with are actually higher. For instance, a 25,000-kVA, 400-volt circuit-breaker has to deal with a short-circuit current of 35,000 r.m.s. amperes, while in a 2,500,000-kVA, 280-kV breaker the corresponding current is only 5,000 amperes. In other words, the smaller piece of apparatus has to interrupt a fault current seven times greater than the larger equipment, while the mechanical stresses produced by this current are 50 times as great. It is clear, therefore, that in the design of this class of equipment many difficult problems have to be solved.

From this point of view, Messrs. Cox and Drucquer's paper is a valuable contribution to engineering literature, for it gives the reader a clear insight into the mind of the designer, together with one particular solution of the difficulties that have to be faced. As will be seen from the abstract which we gave on page 383 of our issue of last week, the authors recommend that circuit-breakers for the duties specified should be of the air-break type. Their reasons are that, though oil circuit-breakers have a definite sphere of usefulness in circuit interruption, especially at the higher voltages, they also have the disadvantages that contact burning is relatively severe when switching is frequent at currents up to about ten times the normal full-load value, that the total-break time is relatively long, and that their use involves a distinct fire danger. This standpoint, it may be emphasised, was only challenged by one speaker in the discussion. He pointed out that, on the whole, oil circuit-breakers were cheap, reliable and compact, though he admitted that there were cases where air circuit-breakers were desirable. The views expressed by the authors, however heterodox to the users, may, therefore, be taken as representative of the latest school of thought. They are, in fact, probably based on the results of recent testing experience. As Mr. W. A. Coates pointed out, the air circuit-breaker is one of the oldest methods of interrupting electrical circuits and even the authors' design does not contain any novel features. It does, however, combine science and practice in such a manner that results, as the test data show, are eminently satisfactory.

In designing alternating-current circuit-breakers, particular attention must be paid to the phenomena which occur on making the circuit, as the first loop of the making current may reach 2½ times the breaking current, a state of affairs which gives rise to considerable electromagnetic forces and difficult problems of contact welding. Robust mechanism and robust contact parts are therefore essential. On the other hand, the structure necessary for blowing out the arc can be small and simple compared with what is necessary when direct-currents have to be dealt with. As regards the contacts, the best are found to be those of the butt or contactor type, in which the loop blow-off effect in the lower part is used to counteract the current pinch and blow-off effects in the upper part of the mechanism. Such contacts, when reinforced by reasonable spring-pressure, can carry 20,000 amperes satisfactorily without spot-welding taking place, while up to 25,000 amperes such slight spot-welding as occurs is easily broken by the wiping action, which takes place between the contacts when the circuit is opened. The latter figure represents the upper limit on breakers which are designed to close on a short-circuit and latch home, so that for still larger currents multiple contacts must be used. Where, however, instantaneous tripping devices are employed, the rating of a single contact can be increased to 50,000 amperes. Heat runs have demonstrated that arcing contacts capable of dealing with 25,000 peak amperes have a normal continuous-load capacity of 200 amperes. It is not necessary, therefore, to add main contacts, unless the continuous capacity is above that figure. When silver-faced, such contacts will also carry 25,000 peak amperes satisfactorily, the magnetic blow-off effect being reduced to extremely small proportions by making the bridging member short, and by separating the main lead-in conductors as much as possible. The main contacts, where necessary, must be sub-divided in the same way as the arcing contacts.

As regards the mechanism, this must be made strong enough to close the breaker against the electromagnetic forces associated with the peak current and at the same time must overcome the very considerable shearing forces involved in wiping the burned contacts. When power operated, it must not wreck itself when closing against the much lower forces associated with no load, nor when opening on short-circuit. Finally, it must be trip free. A further point to which attention must be given in the manufacture of such breakers is the design of the arc chutes, which are not required to ensure rupture, but to prevent wandering and so causing arcs to earth and between phases. The requirements of this part of the equipment, as set down by the authors, are that the magnetic field, which is necessary to keep the arc moving continuously up the chute, so that it is extended and extinguished at the first or second current zero, should be a minimum. The distance between the plates of the chute should also be short enough to prevent the arc unduly lengthening itself by zig-zagging, and long enough to ensure that the free movement of the air is not impeded by strangulation. Finally, the length of the horns should be such that the cathode spots formed at their ends are far enough apart not to cause restriking. It is pointed out that the effectiveness of the chutes is greatly increased by fitting phase barriers between them, so that the incandescent air and the metal vapour resulting from the arc are cooled before striking earthed metal.

NOTES.

THE CENSORSHIP AND INSTITUTION MEETINGS.

FROM the outbreak of the present war, there were obvious indications that the lessons of the previous war had not gone unheeded; this has been particularly noticeable in the matter of censorship. The first reaction of a democratic nation to any form of censorship of the written or printed word is one of irritation, and it is not surprising that the imposition of a new form, when it might be supposed that the regime had become fairly well established, should arouse a certain amount of protest. The requirement that technical institutions should exercise a somewhat closer supervision over the attendance at their meetings, and should admit no non-member whose *bona fides* cannot be vouched for, has the appearance of an unnecessary piece of official interference, and undoubtedly it has been received as such by many members. On closer examination, however, it is seen to be no more than a logical development of the control already in force over the papers and printed discussions. The increasingly mechanised character of modern warfare obviously demanded that due care should be taken that no technical information should be disclosed, of potential value to an enemy. For this reason, the papers are submitted to censorship before delivery, and the reported discussions before publication in the printed transactions. Between delivery and printed publication, however, there is an obvious opportunity for leakage, by incautious remarks made at the meeting itself, not only in connection with the paper under discussion, but in the course of personal conversations before and after the official proceedings, which might be overheard and subsequently spread farther afield. When so many professional engineers are directly engaged on war work, often at a distance from their normal places of occupation, institution meetings become, to a greater extent than usual, occasions of friendly reunion, and the inducement to exchange views and impressions is correspondingly enhanced. It is to be hoped, therefore, that the slight inconvenience involved in completing a "passport" for each visitor will be accepted as a necessary precaution in the present circumstances. It has been so long the custom to admit visitors on the bare formality of signing an attendance book that a definite reminder is necessary that there are still individual neutrals and ostensible refugees whose presence demands continual watchfulness.

SIR ROBERT SEPPINGS, F.R.S. 1768-1840.

At a time when the work of the Royal Navy is attracting so much attention, it is not without interest to recall the career of a naval constructor, Sir Robert Seppings, whose active service covered the whole of the Napoleonic wars, and who, for nineteen years, occupied the high office of Surveyor of the Navy, a post held to-day by the Director of Naval Construction. Seppings was born in 1768, and died on April 25, 1840. His birthplace was Fakenham, Norfolk, eight miles from Burnham Thorpe, where Nelson was born ten years earlier. His father was a not very successful cattle dealer and the boy was brought up by his uncle, Captain John Milligan. In 1782, he was apprenticed as a shipwright in Plymouth Dockyard, and he steadily rose in his calling. At the age of thirty-two he was master shipwright at Plymouth and four years later was transferred to a similar position at Chatham, which he held until 1813, when he was appointed Surveyor of the Navy by the old Navy Board. His first important contribution to practical shipbuilding was his invention of the "Seppings blocks"—the arrangement of three wedges on the keel blocks in a dry dock by which the examination of the keels and lower timbers of ships was greatly expedited. The first trial with his blocks was made with the San Josef in 1800 at Plymouth, and the invention speedily came into use. For this improvement he received 1,000*l.* from the Admiralty and a medal from the Society of Arts. His second and far more valuable improvement was the introduction of the diagonal principle of bracing the frames of wooden ships so that the hull became a completely-trussed structure. This system was applied to the Kent in 1805, when the ship was in hand for repairs, while the Howe, launched on March 28, 1815, was the first warship laid down and wholly built on the diagonal principle. As might be expected in an age when tradition held sway, the innovation was bitterly opposed by some of the older shipwrights, but on the other hand, critics with mathematical attainments approved of it, and eventually the rounded stern characteristic of Seppings' ships completely superseded the structurally weak "square tuck" that had persisted since Elizabethan days. Though Seppings wrote no book on shipbuilding, he described his improvements in three papers to the Royal Society, and in 1818 he was awarded the famous Copley Medal, the only naval constructor to receive this high distinction. His knighthood dated from August 17, 1819, when it was conferred upon him on board the yacht Royal George when she was under sail. Another honour he received was that of the D.C.L. from the University of Oxford, in 1836. Seppings' career at Somerset House terminated in 1832, when, under the administration of Lord Grey and the reforming energy of the First Lord of the Admiralty, Sir George Graham, the Act of Parliament of June 1, 1832, was passed, abolishing the Navy and Victualling Boards and re-organising the Admiralty much as it exists to-day. The Dictionary of National Biography states that Seppings resigned, but in 1833 a pamphlet appeared, entitled "An Apology for English Ship-Builders showing that it is not necessary the Country should look to the Navy for Naval Architects," which referred to "the recent dismissal of Sir Robert Seppings from the office of Surveyor for the Navy and the appointment of Capt. Symonds, R.N., as his successor." After his resignation or dismissal, Seppings settled at Taunton, where he died in 1840, at the age of seventy-two. A tablet to his memory in St. Mary's Church, Taunton, has inscribed upon it the following sentence from the Report of the Committee of Finance of the House of Commons, dated April 30, 1819: "To his ability and exertions the country is mainly indebted for its most valuable improvements in naval architecture which will confer a lasting benefit on the British nation."

THE DISTRIBUTION OF PRODUCER-GAS FUELS.

Although disappointment is being expressed in some quarters at the slow rate of progress in the application of gas producers to road vehicles, a considerable amount of spade work has been accomplished. One of the basic difficulties that has to be overcome is that of ensuring a supply of suitable fuels, and it may be recalled the first step in this direction, that of preparing a specification of such fuels, was undertaken and carried out by the Producer Gas Fuels Committee of the Coal and Carbonisation Industries. This specification, which was reproduced in ENGINEERING, page 150, *ante*, is being considered by a British Standards Institution Committee with a view to its issue as a British Standard. The British Coal Utilisation Research Association is now investigating the factors in the national distribution of the fuel, and by means of a questionnaire, the help of garages and commercial-vehicle users is being sought to ascertain the probable requirements more precisely. There is no existing sales machinery which can be used for the retail distribution of the fuel at the roadside. A method which may be adopted is to arrange for the fuel to be available at key points throughout the country, using for this purpose garage and motor engineers who specialise in commercial-vehicle work. Several such firms are already interested in producer-gas operation and have expressed a wish to stock the fuel. One of the main objects of any scheme which may be adopted will be to keep the price of the fuel down to the lowest possible figure. So far, no retail price has been decided upon, but it is estimated that it will be about 6*l.* per ton for normal fuels, with an extra charge of about 7*s.* 6*d.* for those which come under the category of specially dried fuels. This will be a national price for the whole of England, Wales and the South of Scotland, independent of the distance from the colliery or carbonisation plant. Operators using fairly large quantities of fuel, and who have storage facilities, will be able to save by buying in bulk, as in the case of petrol or Diesel oil.

THE LOSS OF H.M.S. "THETIS."

(*Concluded from page* 393.)

IN last week's issue of ENGINEERING, we summarised the circumstances surrounding the foundering of H.M. submarine Thetis on June 1, 1939, as given in the Report of the Tribunal of Inquiry,* presided over by Mr. Justice Bucknill. Part V of the Report, dealing with the causes of the disaster, is given below in abridged form.

(1) *The Blocking of the Test Cock of No. 5 Rear Door.*—The blocking of the test cock with Bitumastic enamel and the failure of any one to notice it, played an important part in producing the disaster. The enameller said he first put a plug in the hole in the rear door, but no one else realised the danger. When the rear doors were surveyed after the Thetis was raised, not only No. 5 test cock but No. 4 test cock also was blocked by Bitumastic enamel. If the enameller put in the plug, it must have fallen out while he was smoothing over the enamel with the blow lamp. Cammell Laird's men were not employed in putting on the Bitumastic. Their charge-hand painter, Mr. Taylor did not think there was any chance of the Bitumastic getting into the test-cock holes, and took no steps to avoid their getting blocked. After all the Bitumastic work to the tubes and doors had been completed, it was the duty of the Admiralty overseer, Mr. Grundy, to examine it, and if satisfied, to pass it. Mr. Taylor asked Mr. Grundy to do so. He admitted he was aware of the test-cock hole in the rear door, and of the reason why a rimer was supplied.

If Mr. Grundy had examined the interior of the doors he should have noticed that the test-cock hole was blocked. He would certainly have done so if he had tested each hole with the rimer. By some perverse mishap, the enameller did not take sufficient care to see that the test-cock hole was kept clear, the Admiralty overseer did not use the rimer, Lieutenant Woods did not use it, nor anyone else from May 15 to June 1.

In the Royal Navy no routine was specifically laid down about clearing out the test-cock holes. Lieutenant Woods said it was his practice to instruct the Torpedo Gunner's Mate to rime out the holes frequently, but he had not told Chief Petty Officer Mitchell to do so because he was not yet in charge of the tubes.

(2) *The Opening of the Rear Door of No. 5 Tube when the Bow Cap was Open.*—This act was the immediate cause of the disaster. Lieutenant Woods opened the rear door to satisfy himself that the tube was empty, and the bow cap was watertight. He was convinced that the bow cap was shut because (i) no water came out of the test cock; (ii) Mr. Robinson, Cammell Laird's foreman, told him that Nos. 5 and 6 tubes were not meant to be full; (iii) he had seen the mechanical indicator at "Shut"; and (iv) Leading Seaman Hambrook had told him the control levers were at "Shut."

There is no direct evidence as to why, when, or by whom the bow cap was opened. Three assumptions appear reasonable. One is that the bow-cap telemotor operating mechanism, and the bow-cap mechanical indicator were in proper working order. They worked properly during their many trials before the accident, they worked properly after the Thetis was raised. Another assumption is that No. 5 tube was empty and the bow cap closed before any steps were taken to put the trim on the Thetis in the basin before she started out on June 1. The third assumption is that skilful and careful men working under normal conditions and without the stress of undue haste or fatigue do their work with skill and care.

Why was the bow cap open? The only adequate reason for opening it was to fill the tube to trim the ship for the diving trial. Those responsible for trimming the submarine for the diving trial in accordance with the trim statement intended to fill this tube. The trim statement was presumably made out by Mr. Hill, principal ship overseer,

* *Report of the Tribunal of Inquiry into the Loss of H.M.S. "Thetis."* Cmd. 6190. London: H.M. Stationery Office. [Price 1*s.* net.]

or on his instructions, and was handed to the commanding officer. The trim statement recorded that Nos. 5 and 6 tubes were full, and the others were empty. In corroboration of the trim statement that No. 5 tube was full, No. 6 tube was more than half full when Lieutenant Woods tested it after the Thetis had been shut down for the dive, and it seems likely that No. 5 tube would be in a similar condition.

The bow cap of No. 6 was found to be shut when the Thetis was raised. It is very unlikely that, if No. 5 bow cap was opened before the Thetis left the basin, it would be left open all the morning. One assumes, therefore, that No. 5 tube was filled before the Thetis left the basin and, if it was filled by opening the bow cap, the bow cap was closed at once, the valves to the lever were shut, and the lever left either at shut or put at neutral. On the other hand, when Lieutenant Woods asked Mr. Robinson whether Nos. 5 and 6 tubes were meant to be full, Mr. Robinson said "No." There seems, therefore, to have been some misunderstanding whether No. 5 tube was meant to be full, or was full, or not. It is possible, but improbable, that shortly before Lieutenant Woods opened the rear door, someone opened the bow cap in order to fill No. 5 tube for trimming purposes without the knowledge of Lieutenant Woods and left the bow cap open by mistake. If this is not the reason, the only explanation appears to be a manipulation of the lever towards the open position, when the manipulator did not realise that power was thereby being applied to the bow cap, or a creeping open of the cap, when the power was turned on.

When was the bow cap opened? It is unlikely that this happened before the power was turned on at Lieutenant Woods' request, not many minutes before the accident. If the evidence of Lieutenant Woods is believed, that he inspected the mechanical indicator of No. 5 tube and saw it was at shut, after he had asked for power to be turned on, the bow cap could not have been open at the time of his inspection. Lieutenant Woods was a clear, candid and completely honest witness. His observation of the test cocks of the other rear doors, so far as it can be tested by their condition when the Thetis was raised, was close and accurate. It is likely that he would inspect the mechanical indicators of the bow caps before opening the rear doors, to satisfy himself that they were at shut. I am satisfied that he examined the mechanical indicators, and that he then saw No. 5 indicator was at shut, after he had asked for power to be turned on.

It is a reasonable assumption that Hambrook left or put the other five levers in the position of approximately neutral in which they were found. Lieutenant Woods said that the neutral position was the normal position for the lever to be kept in. There was at that time no Admiralty order about the use of the neutral position. In my view, the observation of No. 5 mechanical indicator by Lieutenant Woods, in its shut position, establishes that the bow cap was opened after he made his examination and he requested the power to be turned on, but establishes no more than that. There is no other evidence which throws any light on the question as to when the bow cap was opened, except, perhaps, the evidence of Lieutenant Coltart that he saw bubbles of air just forward of the stem of the Thetis almost immediately before she finally disappeared. I do not think that his evidence throws any light on this question.

Who opened the bow cap? According to the evidence, Hambrook was the last man who attended to the control level. There is no definite evidence that Hambrook on this occasion handled No. 5 lever. Hambrook was away from the lever for perhaps ten minutes, while he was opening the rear doors of Nos. 1, 2, 3 and 4 tubes, and during that time it is possible that some one moved the lever to open either by accident or on purpose. If so, after opening the bow cap the lever must have been put to the approximately neutral position in which it was found. The improbability of this movement by some unknown person is that Mitchell, who was at the telephone with another rating, and Lieutenant Jamison, would almost certainly have seen any man come into the tube compartment. If an order had been given from the control room for the tube to be flooded, without the knowledge of Lieutenant Woods, just before the accident, the fact would have been well known.

If no one moved No. 5 lever after Hambrook went to it, Hambrook possibly opened the bow cap by inadvertence, by pushing the lever forward to the open position either to ease it, or while he was turning the wheels which operate the valves. To decide that he pushed the lever to "Open" solely because he was, according to the evidence, the last man to have attended to the lever, would be to guess, and would be unjust. It is possible, and this seems the least improbable theory, that the bow cap crept open; that the creep started when the power was turned on at the request of Lieutenant Woods and continued until the bow cap was wide open and that the lever was then put into the neutral position in which it was found. Possibly, during the morning when men were moving about in the compartment, No. 5 lever was moved towards the open position sufficiently for the bow cap to start creeping open as soon as the power was turned on. The alley way, in which the panel of levers is fixed, is so narrow that a man has to walk along it sideways. This, however, involves the conclusion that Hambrook did not put the lever effectively to shut or find it at shut, after the power was turned on to it, and that he must have put it from the creeping position to the approximately neutral position in which it was found. It also involves this, that Lieutenant Woods inspected the mechanical indicator before the power was turned on to No. 5 bow cap.

(3) *The Failure to Effectively Close the Port Water-Tight Bulkhead Door.*—The port water-tight door of No. 25 bulkhead was found closed when the Thetis was raised. One of the 18 turnbuckles, at the top of the door, was in the securing position and screwed very tight. Of the remaining 17, five were in their stowage clips and 12 were hanging loose. When the tube compartment was flooded there was delay in getting the door to, because it is heavy and opens forward. Then one of the lower turnbuckles, on being taken from its catch, fell down between the door and the coaming and had to be extricated. In the meantime, some of the water rising in the tube compartment flowed aft through the water-tight door space into the stowage compartment. Then as the weight of water canted the bows down, the water in the stowage compartment flowed forward against No. 25 bulkhead and put the lower part of the door coaming under water. Furniture and fittings slid down into the doorway, making it impossible to secure the lower turnbuckles. If only another turnbuckle could have been made fast at the bottom of the door, the flood would have been stayed, the water pumped out of the stowage compartment and blown out of the tube compartment, and the Thetis would have come to the surface.

(4) *The Failure of Those on Board the Thetis to Refloat Her.*—When Captain Oram went into the forward escape chamber about half an hour after the accident he estimated that the stowage compartment was about three-quarters full. The total capacity of the chambers is 90 tons. Assuming that the bulk of this water had come in after the door was closed, the rate of inflow was about 135 tons an hour. The capacity of the pumps of the Thetis at the depth at which she was lying was approximately 70 tons an hour, so that pumping would not have been effective. It was not possible to blow the water out through No. 5 tube because the torpedo embarking hatch is not constructed to resist internal pressure of any considerable force.

The gallant efforts made to get forward by using the forward escape chamber failed when the chamber was being flooded up. It is doubtful whether, under such high pressure, any man could have made his way to the torpedo tube compartment, close the tube door, and then go back to the stowage compartment, open two valves there to enable the pumps to be applied and return to the chamber. It is hardly necessary to point out the peril of the service for which Lieutenant Chapman, Lieutenant Woods, Chief Petty Officer Mitchell and Petty Officer Smithers volunteered.

(5) *Failure of Assistance from Outside.*—The main reason why the outside efforts to save the lives of those on board the Thetis were unsuccessful was the failure to locate her position during the 16¾ hours from 3 p.m. on June 1 to 7.50 a.m. on June 2. Meanwhile, the air became very foul, partly due to the unusually large number of men on board, partly due to the fact that a considerable amount of hard manual work was done. About four tons of water were carried away by hand from the forward escape chamber when it was drained down three times. Cammell Laird's men also worked during the night to adjust the pipes for pumping.

Lieutenant Coltart, on the Grebecock, when the Thetis suddenly disappeared, probably found it difficult to decide upon his proper course of conduct. The Grebecock was in a strong tide and in a depth of water in which she could not anchor without shackling her two cables together. She had no marker buoy to indicate the place, and it did not occur to anyone to improvise one. At first, he thought that the Thetis might have become suddenly heavy, because one of the vents to a main ballast tank had stuck, causing undue lightness; then she trimmed down and, while this was being done, the vent opened and the ballast tank flooded, making her too heavy. This defect, he thought, could be remedied without difficulty by pumping out her auxiliary tanks. It seemed to him, therefore, that there was no sufficient reason for deciding that a serious accident had happened. If so, the Thetis would fire a smoke candle or release an indicator buoy. Lieutenant Coltart watched for such a signal but saw nothing. There is no precise evidence that a smoke candle was discharged until a considerable time after the vessel sank. Of the three candles on board two were still on board when she was raised. The wireless log first records the firing of a smoke candle at 9.10 p.m. Twenty-one indicator lights were also fired, probably later than the candle. The forward indicator buoy was released about 3.30 p.m., but it may have broken adrift at once.

Lieutenant Coltart eventually decided to send a message to Fort Blockhouse by the Grebecock's radio-telephony. There was nothing in his message to arouse anxiety in the minds of those who transmitted it and, by a persistent ill-fortune, Fort Blockhouse did not receive it until 6.15 p.m. By the time the Grebecock anchored she had moved four miles from the place where the Thetis sank. This fact, unknown to those on board the Grebecock, probably explains why they did not see the smoke candle, the indicator lights or the indicator buoys. The position of the Grebecock at anchor misled H.M.S. Brazen and the S.S. Vigilant and caused them to start their search in the wrong place. They were also misled by the reports sent from the aeroplane of a buoy miles from the actual position. It was not until 7 a.m. on June 2 that the Brazen and Vigilant decided to search substantially to the eastward of the Grebecock.

The next question is whether there was any undue delay ashore in sending any vessel or aeroplane to search. The Thetis was due to surface not later than 5 p.m. Until that time, in the absence of any message from Lieutenant Coltart, there was no reason for those in charge at Fort Blockhouse to suppose that anything had gone wrong with her. The first order for search by ship was despatched at 6.22 p.m. to H.M.S. Brazen in code, which caused some delay in deciphering. At 6.50 p.m. the first message was sent for search by aeroplane. In the result, no ship or aeroplane arrived upon the scene and started to search until about sunset at 9 p.m. The difficulty of deciding when to order a search for the Thetis was considerable. At 5.50 p.m. the officer at Fort Blockhouse thought it premature, before there was any certainty that a casualty had occurred, to set in motion the elaborate procedure for dealing with a submarine casualty. Taking all things into consideration, there was some delay in organising a search. This delay was not caused by any lack of vigilance and attention to the Thetis by the responsible staffs ashore. It was due partly to the absence of any reason to suppose that such a strange accident would happen, partly to a desire not to cause unnecessary alarm, and partly to a reluctance to set a number of ships and men in motion, as required by the procedure laid down for such a case, if it

proved to be a false alarm. The Admiral in charge of submarines at Fort Blockhouse was away ill, which probably made a decision to treat the Thetis as a casualty more difficult for those in charge. Once a decision had been arrived at, on receipt of Lieutenant Coltart's belated message, everything was done that could reasonably be expected. Those who decided to rely on H.M.S. Brazen had no knowledge and no reason for supposing that the Thetis could not signal to the Brazen.

It is uncertain whether the stern of the Thetis would have remained above the water if no towage at the stern had taken place and it received no support. It is not possible to say why the stern suddenly lost its buoyancy. It may be that air slowly escaped from the after main tanks and was replaced by sea water; another possible reason was the opening of the forward door of the after escape chamber while the after flood valves of the chamber were open. It is doubtful whether any of the men in the Thetis, if they had been able to open the manhole door in the bulkhead, could have climbed through it into Z tank. Even if a man had been able to do this, it would have been almost impossible for him to get through the manhole on the top of Z tank above the rudder head. The space between the deck and the rudder head is only 9 in.

After Captain Oram came to the surface with the plan, those in charge of the Vigilant at first tried to carry it out. It was then a hopeless project having regard to the lack of the necessary material on the spot, and the short time left in which life on board the Thetis could continue. There was a shortage of ten Davis escape sets after the flooding of the torpedo stowage compartment, in which 29 sets were stored. Again, nine sets were left in the general store ashore after they had been taken there to be overhauled. The result was that the Thetis sailed with only 122 sets, and with 29 of these unavailable, had only 93 sets for use.

If those in charge of the salvage operations had concentrated their efforts on holding the stern out of the water and in getting oxy-acetylene gear as soon as possible to cut a hole in the stern, more of the men might have been saved. The danger of cutting such a hole was that, if the stern lost its buoyancy and the hole sank beneath the surface, Z tank and the steerage compartment would be flooded. This danger could have been avoided by lashing the stern of the Thetis to the Vigilant.

The reason why this method of escape was not hurried on was that those in charge of the salvage operations expected the majority of those on board the ship to escape by the Davis escape apparatus and hoped to salve the ship and the rest of those on board, by adopting the salvage plan. When any more men failed to emerge, those in charge of the salvage realised that all life would cease in the Thetis long before the plan became effective. They then decided to tow at the stern to keep it out of the water while a hole was cut in Z tank. The oxy-acetylene gear did not arrive until 2.30 p.m. and before the hole was cut the tow rope parted, and the stern sank.

(6) *The Failure to Escape from the Thetis.*—In the absence of any definite evidence, one can only surmise why no more men came to the surface after Arnold and Shaw had escaped. Examination of the Thetis proves that no serious fire or major casualty occurred after Shaw and Arnold escaped. A possible explanation lies in the increase in the angle which the Thetis took as the tide rose and lifted her stern while her bows remained on the ground. When the water started to fall on the ebb tide, those who were trying to save the crew towed at the stern to try to effect an entrance through Z tank, and thereby increased the angle, some of the witnesses said, to 60 deg.; if so, it is very doubtful whether the men could have made their way into the escape chamber.

There is also the problem of the four men who were put in the chamber together. There is no reason to think that the escape apparatus used by any of these four men was in any way defective. In the greatly overcrowded state of the chamber it was probably difficult to open the escape hatch. The men in the Thetis who were employed by Cammell Laird's had had instructions in the use of the Davis apparatus at a lecture ashore, but they had not had any practical experience of its use in a tank. The over-crowded state of the chamber, only designed for two men, would, in itself, make the proper use of the apparatus much more difficult. With the big angle at which the ship was, and with the exhausted condition of the men, it is not surprising that they failed to work the escape apparatus or the chamber satisfactorily. The reason why four men went into the chamber is obvious. The air in the submarine was so foul and the number of men in it so many, that time for escape was fast running out.

It is clear from the examination of the Thetis that no attempt was made at any time to use the forward chamber as a means of escape. This chamber was about 150 ft. below sea level at high water, and the physical pain already experienced trying to use it was probably the reason why it was not used again. The evidence of Mr. Brock about the bubbles of air which he saw indicates that two separate efforts to leave by the after escape hatch were made soon after Arnold and Shaw appeared, but failed because the hatch could not be opened.

The evidence from the Thetis herself leads to the surmise that such efforts were made and failed, and that no further attempts were then made because Mr. Brock was heard working on the stern and everyone collected in the two after compartments. After the Thetis suddenly moved and Brock had to get off the stern, another final effort was made by two men to escape. They were unable to open the hatch because of the partially-engaged position of the outside clip, and either opened the forward door of the chamber, or the door came open by accident. In the result, the water poured into the engine room. The watertight door leading from the engine room to the steerage compartment was then shut, and no one had strength or understanding to shut off the after main valve of the escape chamber. In consequence, the stern gradually lost its buoyancy and sank about half-an-hour later, when the tow rope parted.

THE LATE SIR GEORGE BUCHANAN, K.C.I.E.

WE regret to record the death of Sir George Buchanan, which occurred at Ditchingham, Norfolk, on Sunday, April 14, at the age of 74. Sir George had had a distinguished career as a civil engineer, and played a leading part in connection with the organisation and administration of the port of Basra during the Mesopotamian campaign of the war of 1914-18. Some years later, he was connected with the Back Bay reclamation scheme at Bombay.

George Cunningham Buchanan was born on April 20, 1865, and was educated for his father's profession of civil engineer on the River Tyne, where he was first pupil of Mr. J. Watt Sandeman and then improver with Mr. P. J. Messent, chief engineer of the Tyne Commissioners. Later he was engaged on the construction of the Albert Edward Dock and pier works on the same river, and acted as resident engineer of the graving dock then being built. In 1886 he went to Venezuela, where he entered the service of the Quebrada Land and Copper Company, while two years later he joined Messrs. Perry, Cutbill, De Lungo and Company, with whom he was engaged on mine and railway surveys and railway construction. At a later date, he acted as assistant engineer to Sir John Fowler, Baker and Ketchum in Nova Scotia, and was also assistant engineer on the reconstruction of the Central Northern Railway in the Argentine Republic. During this period he was first in charge of some 450 km. of line, and then chief resident engineer.

After further railway work in Spain and Jamaica, he returned to this country in 1895, to become resident engineer at Blyth, Northumberland, where he was responsible for the construction of a large graving dock, while a year later he was appointed chief engineer to the Dundee Harbour Trustees. In 1901, he became chairman and chief engineer of the Rangoon Port Trust, a position he held for the next 14 years. During this time he designed new port works and carried out a training scheme on the river, being appointed a Companion of the Order of the Indian Empire for his services. He also received the honour of knighthood in 1915. At the end of the last-named year, Buchanan was directed to go to Basra to give assistance to the Commander-in-Chief of the Mesopotamian campaign, Sir John Nixon, in all matters concerned with the port, its administration, engineering works and river conservancy. For his work in this connection, which is described in his book, *The Tragedy of Mesopotamia*, he was twice mentioned in dispatches, and was promoted to be a Knight Commander of the Order of the Indian Empire.

After the war, in partnership with Mr. C. S. Meik, he was appointed consulting engineer for the Back Bay Reclamation scheme at Bombay. This scheme, which was fully described in ENGINEERING for August 21 and September 4, 1925, was designed to relieve congestion and enlarge the residential areas of the town and island, and involved the reclamation of some 1,145 acres from the sea. The main work consisted of the construction of a sea wall about 4 miles long and roughly parallel with the peninsula, and the filling up of the reclaimed area by suction dredgers with silt obtained from the bed of the sea in Back Bay and the harbour. This undertaking proved to be of greater difficulty than was anticipated and the report of a committee which was appointed to inquire into the matter showed that while under the original estimate the scheme was to have been completed in five years at a cost of 2,825,900*l.*, it would actually require twenty years to carry it to success and would cost about 8,000,000*l.* The reasons given for these discrepancies were that much less silt could be obtained from the sea bed than had been anticipated, while not only had the costs of materials and labour risen, but the value of the land had decreased. In the event, only some three-eighths of the original scheme was undertaken and dry filling instead of silt was utilised. Sir George held that in spite of the dredging plant having been mishandled it had performed nearly double the work that had been attributed to it. He, therefore, remained of the opinion that there was no reason why the work should not have been completed within the cost and time sanctioned. He also requested the appointment of an independent committee of investigation. Such a committee was, in fact, formed, but did little more than confirm previous findings.

In 1922, Sir George went to South Africa to report upon the harbours of the Union, while in 1925 the Commonwealth Government called him to Australia to make an exhaustive examination of transport facilities. He was elected an associate-member of the Institution of Civil Engineers in 1891 and transferred to the class of member in 1899. He was awarded the Watt Gold Medal in 1915-16 for a paper on "The Rangoon River Training Works."

THE LATE SIR WILLIAM MEADE-KING.

WE also regret to record the death of Sir William Meade-King, who died at Walford, Taunton, Somerset, on Wednesday, April 10, at the age of 81. William Oliver Evelyn Meade-King was born in London on December 14, 1858, and was educated at Eton, after which he became the pupil of Mr. J. F. La Trobe Bateman, a past-president of the Institution of Civil Engineers. He then became a member of the staff of Mr. T. E. Harrison, engineer-in-chief of the North Eastern Railway, and was engaged under him as assistant resident engineer on the construction of the Alnwich and Cornhill Branch. In 1885, he was appointed resident engineer for the Irlam section of the Manchester Ship Canal, and on the completion of this work he became an engineering inspector under the Local Government Board, a position he retained until his retirement some years ago.

During his retirement, Sir William, who received the honour of knighthood in 1929, took a great interest in the local government of Somerset, being an Alderman of the County Council for some years, and serving as High Sheriff in 1931-32. He was also a Justice of the Peace, and president of the Taunton Division Conservative Association. He was elected an Associate Member of the Institution of Civil Engineers in 1887, and was transferred to the class of member in 1890. His contributions to the *Proceedings* included papers, in conjunction with Mr. W. Elliott, on "The Manchester Ship Canal," for which they were awarded George Stephenson Medals and Telford Premiums.

BIBLIOGRAPHY ON PRODUCTION OF STEEL SHEET AND STRIP.—The City Librarian of the Sheffield City Libraries, Central Library, Sheffield, 1, has sent us a copy of the recently-issued *Research Bulletin No.* 3, which consists of a select bibliography of books and articles on the production of steel sheets and strip. All the books and periodicals referred to may be consulted in the Science and Technology Department of the Central Library, on weekdays between the hours of 9 a.m. and 9 p.m.

FIFTY YEARS OF MARINE ENGINEERING.*

By Professor A. L. Mellanby, D.Sc., LL.D.

(*Concluded from page* 382.)

Besides the Scotch boiler, some limited use was made of the locomotive type in high-speed vessels. Higher pressures and the desire to cut down weight were responsible for the introduction of the water-tube boiler, a type of steam generator that had been made by Gurney in 1826. In this early example the provision of outside downcomers to promote circulation is a marked feature. The Belleville boiler was introduced into the British Navy in 1894 and since then the adoption of water-tube boilers such as the Yarrow, Thornycroft, and Babcock and Wilcox has become common practice. The use of water-tube boilers in large passenger ships is of more recent date. In 1910 an important paper was read in Glasgow by the late Professor J. T. Nicolson, dealing with the use of high gas speeds for boilers. Nicolson had, with the help of our former President, Dr. Daniel Adamson, designed and made an experimental plant in which high forced draughts up to 30 in. water gauge were employed. The value of the work done by Nicolson in preparing the way for the modern high-duty boiler cannot be over-estimated. Forced and controlled water circulation through economiser and evaporator tubes and high speeds with definite paths for the hot gases over the heating surfaces anticipated the main features of many of the modern examples of the high-duty steam generator. In addition, he laid emphasis upon the importance of radiant-heat reception and gave practical examples of how it could be calculated.

With this brief review of high gas speed and forced water circulation characteristics, some of the modern types of steam generator so largely used in Continental vessels may be referred to. They are capable of generating steam at high pressure with safety, using plant of minimum weight and volume. To secure the reduction of heating surface, intense radiation, high gas speeds, and controlled positive water and steam circulation are employed; for reduction in combustion chamber volume, high rates of heat release are aimed at. The particular feature of the La Mont boiler is the forced circulation of the water through the evaporator tubes. The European development of this boiler commenced in 1928, and since then it has been used to a large extent on the Continent for vessels of war and for merchant and passenger ships. It has also become popular for use on land and large examples of it are to be found in central power stations in this country. A La Mont boiler has been built for the British Admiralty and fitted in one of H.M. destroyers. In the Velox boiler we have an example not only of forced water circulation but also of exceptionally high rates of heat liberation in the combustion chamber. Up to now, these boilers have been used more on land than at sea. There is, however, the well-known example of the Athos II, a vessel belonging to the Messageries Maritimes, in which a Velox boiler is installed, capable of producing 76,000 lb. of steam per hour at pressure of 685 lb. per square inch and a temperature of 840 deg. F. Examples are also to be found in a foreign navy, and an experimental plant was built some time ago for the British Admiralty. In the Loeffler boiler the heat from the furnace gases is received by tubes containing steam alone. A Loeffler boiler is installed in the Conte Rosso, and on its acceptance trials generated 45,320 lb. of steam per hour at a pressure of 1,920 lb. per square inch and a temperature of 921 deg. F. There are many successful examples of these boilers in Continental power stations, and four large units have been recently installed in the Brimsdown station of the North Metropolitan Power Company. The Benson boiler has no steam drum and consists entirely of small tubes with their associated headers. Originally designed for generating steam at the critical pressure (3,200 lb. per square inch), the first Benson marine boiler was installed in the Uckermark of the Hamburg-Amerika Line and has been in service since 1930. Since then the critical pressure operation is no longer considered necessary and the latest examples have a working pressure of between 1,100 lb. and 1,200 lb. per square inch and steam temperatures of about 840 deg. F. Installations of such boilers are to be found in vessels belonging to the North German Lloyd and the German Africa lines. The Schmidt-Hartmann boiler consists of a primary and a secondary system; the former is filled with distilled water and the steam generated in it passes through submerged coils situated in the secondary drum and, by giving up its latent heat, evaporates the working steam at a somewhat lower pressure. Boilers of this type, with working pressures of from 500 lb. to 900 lb. per square inch, have been installed in vessels of the North German Lloyd and Argo lines and others are to be found in steam tugs engaged in canal service.

Although this account of modern marine boilers is brief and incomplete, it shows that such steam generators are to-day widely used at sea. From fuller details, with analysis of stress and temperature conditions previously published, it will be found that, in some examples, extreme pressure and temperature conditions must impose severe working stresses on the boiler tubing. The ability to work with confidence under such conditions is largely due to the immense amount of laboratory work that has been carried out upon materials at high temperatures. In this country we have to acknowledge the large amount of valuable information now available from the research work done at the National Physical Laboratory and to that inspired by Dr. R. W. Bailey and carried out at the works of the Metropolitan-Vickers Electrical Company in Manchester. But above all, we must look with gratitude to the pioneering investigations of Mr. J. H. S. Dickenson and Dr. F. C. Lea.

Diesel Engines.—There are certain features in the development of the oil engine for marine propulsion upon which it may be interesting to dwell. In 1912, the Jutlandia was equipped, by Messrs. Barclay, Curle and Company, with two sets of Diesel engines, of single-acting four-stroke cycle air-injection type, driving twin screws, each engine having eight cylinders 20¼ in. diameter and 28½ in. stroke. On trial they developed 2,500 indicated horse-power with a consumption of 0·34 lb. of shale oil per indicated horse-power hour. The output of Diesel-engined vessels from British shipyards and engine shops has since proceeded at a rapid rate, although between 1914 and 1918 little was done, except in the building of submarine engines. In the early stages of development cracked cylinder heads, liners, and pistons were of fairly frequent occurrence; ignition and carbon formation troubles were not unknown; and little information was available on the effects of different qualities of fuel oils upon running performance. To-day, such troubles are rarely experienced, the improved situation being largely due to systematic research and experiment and to the consequent better appreciation of the conditions obtaining in the cylinder during the working cycle. For such work much credit is due to the British Marine Oil Engine Manufacturers' Association, the members of which, in 1917, decided to institute a research section in Diesel engines. Work upon the strength of cast iron at high temperatures was instituted, and it was soon appreciated that only tests of long duration, in which the material was continually stressed while at high temperature, could give reliable results. Other experiments were made upon wearing properties, and upon growth after repeated heating and cooling, until, finally, a composition of cast iron was arrived at which had high tensile strength, resistance to growth, and good wearing properties.

At the same time, the necessity was appreciated of ascertaining the temperatures attained by the metal of the cylinder heads, liners, and pistons under working conditions, researches being put in hand with an experimental engine fitted with thermocouples. These points settled, attention was directed to the fuel-injection apparatus, experiments being made on the effects of different types of spraying upon efficiency and cylinder temperature conditions. Methods of overcoming carbon formation at the flame plate under long-continued runs at high loads were discovered. Air and mechanical injection of the fuel were also investigated and the thermal and mechanical efficiencies of the engine under both conditions determined. The effects of different qualities of fuels were also considered, and the working properties of boiler oils and oils from different systems of low-temperature carbonisation were fully demonstrated. Researches were made to ascertain to what extent supercharging could be used with safety to increase the power developed. Full information was also obtained not only upon the relationship between mean effective pressure and degree of supercharging, but also upon the temperatures attained by the cylinder parts under conditions of supercharging. Great credit must also be given to the work of the Marine Oil-Engine Trials Committee founded through the joint action of our Institution and the Institution of Naval Architects. This committee was appointed in 1922 and has now presented six reports, which are to be found in our *Proceedings*.* The engines dealt with in these reports were of the following types: Beardmore-Tosi, Scott-Still, Doxford, Fullagar, Werkspoor, and Polyphemus. It would be difficult to over-estimate the value of the work of this committee to Diesel-engine builders and shipowners.

In the early stages of development one unexpected and generally costly trouble arose in the torsional oscillation problem. Once more the assistance of the mathematician was called for and soon the main features determining the dangerous critical speeds were fully known. To-day, the calculation has become a routine one and before shaft dimensions are finally decided the speeds at which trouble might develop are carefully estimated. One important feature of these calculations is that it is almost impossible to avoid some order of critical speed when running up to full power, while there is also the difficulty that some order might be stimulated at a speed quite close to that under which some running condition might be desirable. It is, therefore, important to know the working stresses to which the shaft is subjected, a combination of mathematical and experimental research being needed. The amount of damping experienced in the engine can only be determined by experiment. A paper by Dr. Shannon* showed how the influence of damping might be estimated, and paved the way to a complete appreciation of its value.

At the Summer Meeting of 1923, it was shown that the popular method of fuel injection was by compressed air. Out of six different types of engine that were then being built on the Clyde, only one, the Scott-Still engine, had mechanical injection. At the present time the airless-injection system appears to hold the field and in view of the early discussion on the relative efficiencies of the two systems it is of interest to note that Mr. Sterry B. Freeman quotes the fuel consumption per shaft horse-power hour for an air-injection engine as 0·44 lb. and for airless injection 0·355 lb. Some years ago the extra cost and complication introduced by the use of a blast-air compressor was claimed to be compensated for by increased efficiency of combustion.

During 1929 the majority of the engines installed in ships were of the four-stroke cycle type, although an increasing interest was being shown by builders and shipowners in the design of two-stroke cycle machines. Developments were also taking place in the manufacture of double-acting engines, and by that time examples of both the four-stroke and the two-stroke cycle types had been completed. Some indication of the advances that had taken place between 1912 and 1930 can be given by the following typical examples. By 1930, the largest motor vessel launched by Messrs. Harland and Wolff was the m.v. Britannic, fitted with twin-screw engines of the four-stroke cycle double-acting type, developing altogether 20,000 brake horse-power at 105 r.p.m. Each engine had ten cylinders and the 1,000 h.p. per cylinder was developed at a mean effective pressure of about 70 lb. per square inch. Sulzer engines had also been built by Messrs. John Brown and Company for the m.v. Rangitiki. This vessel had two sets of five-cylinder engines driving twin screws and developing 10,000 shaft horse-power. The engines were of the single-acting two-stroke cycle type, and under normal running conditions each cylinder developed 930 brake horse-power at a mean effective pressure of 67·3 lb. per square inch. The Doxford engines of the m.v. Bermuda were their first examples of the truly balanced type, in which the inertia forces were minimised by making the stroke of the upper piston less than that of the lower one. The Bermuda was a quadruple-screw vessel developing under normal conditions a total of 11,600 shaft horse-power and on overload 14,000 shaft horse-power. With their excellent scavenging arrangements the Doxford engines were able to run regularly with indicated mean effective pressures of 95 lb. to 100 lb.

Of the engines tested by the Marine Oil Engines Trials Committee, several are no longer built. These include the Beardmore-Tosi, the Scott-Still, and the Fullagar. The Scott-Still engine, in the m.v. Dolius, had the highest efficiency of all those tested by the Committee and is, I understand, still running with remarkably low fuel consumption. Why the Fullagar engine was abandoned I have never been able to understand, as it has since been developed largely for land purposes and has a high reputation for fuel efficiency and reliability. Some idea of the position of the Diesel engine in the merchant service may be obtained from a series of papers recently presented to the Institution of Engineers and Shipbuilders in Scotland. A schedule of dimensions was drawn up by the Council of that Institution for two typical single-screw ships, each of about 9,000 tons deadweight capacity, the first to have a speed of about 10½ knots and the second 14½ knots. The brake horse-power was specified as 2,000 and 5,000, respectively, and the propeller speed as 110 r.p.m. The difference in proposals from different makers show that as yet there is no standard Diesel marine engine. Of the British-designed engines the Doxford opposed-piston type is at present the most popular.

This review of the developments that have taken place in marine engineering during the last fifty years is, I feel, in many respects incomplete, but if I have had any success in imparting my own beliefs, it must be acknowledged how great has been the debt of marine engineers to scientific investigators.

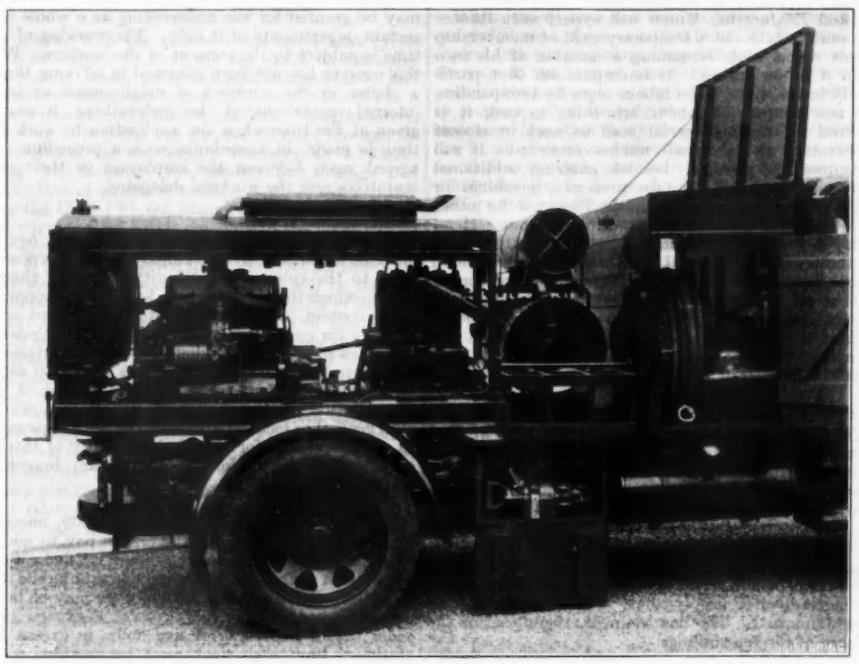
* The twelfth Thomas Lowe Gray Lecture, delivered before the Institution of Mechanical Engineers on Friday, March 15, 1940. Abridged.

* See also Engineering, vol. 118, page 750 *et seq.* (1924); vol. 119, page 397 *et seq.* (1924); vol. 121, page 87 *et seq.* and page 639 *et seq.* (1926); vol. 122, page 767 *et seq.* (1926); vol. 132, page 680 *et seq.* (1931).

* See Engineering, vol. 140, page 675 *et seq.* (1935).

TRANSPORTABLE COMPRESSOR PLANT.

MESSRS. BROOM AND WADE, LIMITED, HIGH WYCOMBE.



ELECTRICITY AS APPLIED TO METALLURGY.*

By A. P. M. FLEMING, C.B.E., D.Eng.

(*Concluded from page* 395.)

Electrostatic Precipitation.—An interesting and quite distinctive application of electricity in metallurgical work is the removal, by electrostatic precipitation, of solid particles from gases produced from the roasting of ores and in blast-furnaces. The gas is passed between two electrodes, one of which is maintained at a high direct-current voltage of the order of 30 kV to 100 kV. This electrode is maintained in a stable state of corona with the emission of electrons which bombard the gas molecules, to cause ionisation. The dust present clings to the ionised or charged particles and thereby becomes charged, and is attracted to the electrodes where it is neutralised and collected.

Power Drives.—There is little need to emphasise the significance of the application of electrical power as a driving and handling means in a large variety of metallurgical operations, such as rolling, drawing, forging, machining, etc. Table III indicates the importance of electrical power applied for such purposes in metallurgical and associated industries. The figures are derived from the 1924 and 1930 Census of Production.

Testing.—A most important application of electricity in metallurgical work arises in connection with methods of testing. In this respect, electricity has proved an invaluable aid to the metallurgist in fine measurement and in research work, as well as in the matter of checking the quality of his materials. Broadly, the methods afforded can be classified as magnetic, electric and X-ray, each of which can be further sub-divided. Using standardised specimens, the composition and heat treatment of which are known, comparisons may be made of unknown specimens by magnetic testing. By suitable exploration of the magnetic behaviour of the specimen in an alternating magnetic field, it is possible to relate the phase and quadrature components of the voltage induced in a search coil, and by comparing these with the standardised specimen, certain inferences can be drawn regarding the composition of the material without destroying the specimen under test. Magnetic methods have also been developed for fault detection, and have been of increasing importance, owing to the tendency to cut down material costs and weight while still maintaining the safety factor by more rigid inspection and care in production. The presence of a fault or change in magnetic composition can be detected by the distortion these cause in the magnetic field, the distortion being located either by a direction indicator such as a magnetic needle or by a moving search coil. Another and most valuable method, however, is that developed largely by the Metropolitan-Vickers Company in which the specimen is magnetised and then subjected to examination under a coating of liquid containing very finely-divided magnetic particles. Thus, when examining bar material for longitudinal cracks, a heavy current is passed down the bar while it is immersed in a bath of finely-divided magnetic particles suspended in a light oil. The particles which can be black or red so as to contrast well with any surface colour or finish, form sharply-defined lines to indicate the flaws. Surface cracks that cannot be detected by the naked eye or even by considerable magnification are readily shown up, and by controlling the direction of the flux, cracks in any direction can be revealed. Electrical methods of fault detection have also been developed. Comparative conductivity tests enable the soundness of metals to be assessed whether they are magnetic or not, *e.g.*, much can be learned concerning the internal condition of a welded joint by passing direct current across the weld and measuring the potential difference across the weld, at various points along its length, by means of a milli-voltmeter. A local increase in resistance, and hence in all probability, a reduction in effective section, is thus determined. X-rays have been applied in two distinct directions, namely, to assist the study of the crystal structure of materials, and to reveal the presence of flaws. Present X-ray methods enable the lattice pattern of any metal or alloy to be ascertained. Each metal has its own distinctive lattice by which it may be recognised, and the distances between the atoms on the lattice can also be determined with very great precision. Moreover, the X-ray structure of a metal or alloy is modified in a marked manner by heat-treatment and cold-working operations and X-ray methods may, therefore, be used to investigate the physical state of the material. This aspect of crystallography is of great value in dealing with the directional properties produced by such operations as rolling and wire-drawing. On the academic side, our knowledge of such matters as equilibrium diagrams, precipitation phenomena, and age-hardening, have been profoundly extended by the use of X-ray methods. The examination of metallic objects for the presence of flaws, holes, etc., which, of course, constitutes a non-destructive method of testing, has become very important, particularly in the examination of castings.

TABLE III.—POWER DRIVES.

Industry.	1924. Power Applied Mechanically. H.p.	1924. Power Applied Electrically. H.p.	1924. Electrification. Per cent.	1930. Power Applied Mechanically. H.p.	1930. Power Applied Electrically. H.p.	1930. Electrification. Per cent.
Metalliferous Mines and Quarries ..	53,360	45,857	46·2	33,433	37,817	53·1
Smelting, Rolling and Founding of Iron and Steel, and Blast Furnaces	1,378,638	1,039,759	43·0	1,404,040	1,319,937	48·4
Extracting and Refining of Copper and Brass	20,133	90,265	81·6	14,797	118,732	88·9
Extracting and Refining of other Non-Ferrous Metals	8,432	55,982	87·0	6,237	82,802	93·1
Gold and Silver Refining	332	4,966	93·7	271	9,270	98·2
Tin-plate	86,725	15,855	15·5	79,015	38,057	32·5
Finished Brass	9,301	17,867	65·8	5,706	24,218	80·5
Wrought Iron and Steel Tubes ..	16,933	84,157	83·3	13,499	112,460	89·2
Anchor Chains, Nails, Bolts, Nuts, Screws and Rivets	15,282	32,311	68·0	18,487	77,921	80·9
Wire	23,276	71,744	75·5	16,292	86,694	84·1

* Thirteenth William Menelaus Memorial Lecture, delivered before the South Wales Institute of Engineers, at Cardiff, on Tuesday, March 19, 1940. Abridged.

TRANSPORTABLE COMPRESSOR PLANT.

LORRY-MOUNTED air-compressor plants have certain advantages as compared with those which have to be towed by, or loaded on to, a road vehicle. Lorry-mounted plant with full tool equipment can be very quickly under way to any job without the necessity of withdrawing a heavily-taxed vehicle from other important work to get the plant and tools to where they are required. For mounting on a standard commercial motor vehicle, the compressor plant should be of compact overall dimensions. The well-known sleeve-valve air compressors, manufactured by Messrs. Broom and Wade, Limited, of High Wycombe, possess marked advantages in this respect, due to the comparatively high speed for which they are designed. Many compressor plants of this type have been built and mounted on standard commercial motor vehicles by the firm for customers both in this country and overseas, and one of the more recent is illustrated in the accompanying figure. Two duplicate plants were built to the order of H.M. Postmaster-General for the Post Office Engineering Department. They comprise "Broomwade" standard SV2 portable petrol-engine driven units embodying a two-cylinder 5¼ in. by 4½ in. sleeve-valve air compressor, directly driven by a four-cylinder engine. The compressor delivers 110 cub. ft. of free air per minute at 100 lb. per square inch pressure when running at 1,200 r.p.m. The set is completely self-contained in the usual way, with radiator cooling and ample air-receiver capacity. The plants in this instance are mounted on the customers' Morris 2-ton commercial chassis in the manner shown, but instead of the usual air-delivery manifold adjacent to the air receiver, the delivered air is led from the after cooler pipe, between the air receiver and the fuel tank, along the length of the chassis to air delivery cocks arranged transversly at the rear of the vehicle.

Plants of this type can carry very complete tool equipment, and the plants for the Post Office are each supplied with "Broomwade" pneumatic tools, comprising two concrete breakers, two clay spades, two backfill rammers and two rock drills, together with an assortment of steels, blades, etc., for each type and four 50-ft. lengths of pneumatic hose. A large tool box is placed between the lorry cab and the compressor. Large doors open on both near and off sides. An upper compartment, covered by the hinged lid, carries the steels, spade blades, etc., in racks, and the blacksmiths' tools, plant tool kit and instruction books in special receptacles. In the lower compartment, the side doors each give access to one concrete breaker and our clay spade, carried one above the other in special racks, to which they are secured by a strong strap. The coiled pneumatic hoses are also carried on racks in this compartment. Supplementary tool boxes are fitted below the level of the foot board on each side of the compressor plant, the one seen in the figure on the off side being for the rock drills and the other on the near side for the back fill rammer. All tool boxes, a rack to accommodate three 2-gallon petrol cans, and the steel canopy side sheets are provided with means for locking to secure the plant and tools against interference or pilfering when the vehicle is left unattended.

LABOUR NOTES.

In March, the home branch membership of the Amalgamated Engineering Union increased from 385,465 to 395,389, and the Colonial branch membership from 36,933 to 37,184. The number of members in receipt of sick benefit decreased from 11,807 to 6,549, and the number in receipt of superannuation benefit from 13,899 to 13,860. The number in receipt of donation benefit decreased from 708 to 602, and the total number of unemployed members from 3,225 to 2,974.

The April issue of the *Journal* of the Amalgamated Engineering Union states that the organisation has been informed by the Engineering and Allied Employers National Federation that their Associations have agreed to the recommendation, relating to holidays with pay, arrived at in conference on January 26. The arrangement was that in cases of accident or sickness (certified to the satisfaction of the employer) the working hours so lost (limited in the aggregate to six weeks in the twelve months between the summer holiday of one year and the summer holiday of the next year) should count as hours worked for the purpose of holiday credits. The agreement operates as from Friday, March 1; it treats the unexpired portion of the present holiday year as six months, and allows working hours lost through sickness or accident to count for the purpose of credits up to an aggregate of three weeks in that period.

Mr. Tanner, the president of the Amalgamated Engineering Union, states in the course of his report of the executive council's proceedings in March that, in company with Mr. Smith, the general secretary, and Mr. Kaylur, he discussed with Mr. Shakespeare and several other representatives of the Admiralty the operation of the "Relaxation Agreement in Admiralty Establishments." As a result, a document is to be circulated to those in charge of Admiralty establishments explaining the principles to be adopted in introducing dilutee labour. It is laid down that in view of the shortage of labour in the dockyards for executing the vital work of maintenance and repair of the Fleet in war time, and the probability of increased work in the future, it is imperative to attract fresh labour to Portsmouth, Devonport, Chatham and Sheerness. Rosyth, too, it is added, will grow in importance as the war progresses, and the work of repair will considerably increase at that dockyard. "If additional labour is to be entered," the document continues, "it is essential that the existing labour in the dockyards should be used to its fullest capacity. That object can be achieved by operating to the fullest extent, whether by piecework or by job contracts, the system of payment by results. The Admiral Superintendents of Dockyards, through their managerial staffs, must keep that object constantly in view."

"It will also be necessary," it is pointed out, "to work more overtime than in peace time. It is not possible to lay down the percentage of overtime to be worked; it will vary department by department. The percentage must be reasonable, and regard must always be paid in this connection to the question of efficiency of output and the general question of industrial fatigue. To utilise, to the full, existing capacity of the dockyards, the three main departments . . . must co-operate closely together, so as to ensure that if skilled labour in one department is not being fully utilised there can be a transference of such labour to departments where it can be used to the full on specific jobs. Such transference will relate only to the performance of jobs within a man's own trade. When such jobs are finished, the skilled labour can be transferred back again to its own department."

"Additional labour in the dockyards," it is stated, "can be secured by a variety of methods:—(*a*) By entering fully-skilled mechanics; this is the normal procedure and requires no explanation; (*b*) By up-grading in appropriate cases, by agreement with the trade union, skilled labourers to the grade of temporary mechanics; where such up-grading takes place, the vacant posts can be filled by up-grading from lower grades within the yard itself; (*c*) By agreement with the trade unions it will be possible to enter as dilutee-mechanics, for the duration of the war, men of slightly less skill than fully-qualified mechanics; some men will be already qualified to perform a specific job, while others will require training before they can be usefully employed; this training in many cases is better carried out in the dockyard itself; in other cases, it is possible to make arrangements with the nearest Ministry of Labour Training Centre, whereby skilled or semi-skilled men are trained in processes or on machines which are likely to be used in the dockyards."

"Where arrangements are made," the document goes on, "for the entry of men as dilutee mechanics, either direct from the Employment Exchanges or through a training centre, the appropriate trade union should be consulted before the appointment is made by the managerial staff. It is anticipated that the Amalgamated Engineering Union will expect such dilutee mechanic to take out a temporary card of membership in this union while remaining a member of his own union if he so desires. It is emphasised that particularly in war time, when labour capacity is expanding and new sources of labour are being tapped, it is essential for the managerial staff to work in closest co-operation with the trade unions concerned. It will sometimes be possible, besides entering additional labour, to re-classify certain processes, machines or occupations whereby men can be liberated for other work and their place taken by dilutee labour. Here, again, in all such cases the closest co-operation with the trade union is essential. It is suggested that where dilutee mechanics are entered, the remuneration should be that of the lowest scale of the appropriate grade." The foregoing statement, it may be added, is additional to, and explanatory of, the agreement between the Admiralty and the Amalgamated Engineering Union signed in London in September last.

The three trade unions of railwaymen have applied to the Railway Executive Committee for an early meeting to discuss a claim for a wage increase of 6*s.* a week for the traffic grades and 15*l.* a year for the salaried staff. In December last, it will be recalled, the three unions—which are the National Union of Railwaymen, the Associated Society of Locomotive Engineers and Firemen, and the Railway Clerks' Association—applied for an increase of 10*s.* a week, and agreed, after negotiations, to take 4*s.* a week as from January 1. The new claim is, therefore, for the balance of the ten shillings.

The Transport and General Workers' Record for April states that "alarmed at the increase in the number of industrial accidents," the union has written to the Prime Minister and also to the Home Secretary asking for a thorough inquiry into the subject. The letter points out that in the view of the executive council "the growth of accidents has been accentuated by long hours of work, excessive overtime, the introduction of inexperienced workers into industry, and the black-out." It also calls for investigation of the problem of factory lighting and ventilation during the summer. "If," it is stated, "the factories are not so adapted as to give more natural light and ventilation, or, in other words, if the black-out is allowed to continue in use on the premises during the hot weather, it will further accentuate the industrial difficulties. It will, in fact, lower the vitality and health of the workpeople, with disastrous results to production." The *Record* adds:—"In war time, particularly, it is essential that everything possible should be done to maintain the health and safety of the workers, and we hope there will be no delay in dealing with the problem to which the union has called attention."

An Order issued by the German Minister of Labour amends the provisions relating to short time in the Order of September 18, 1939. Hitherto unemployment allowances in respect of short time might be granted whenever the hours worked were less than 80 in a fortnight by reason of lack of work. The amount of the allowance represented 50 per cent. to 100 per cent., according to family responsibilities, of the difference between actual earnings and the wage that would have been earned for 80 hours' work. This regulation was based on the assumption of a normal working week of 48 hours. In order to take account of extensions of hours which have become customary, the Minister decided to make the allowance payable as soon as hours worked fell below 96 in the fortnight, provided that the reduction below the customary level brought about by lack of work was at least one-sixth. The customary level is defined as the hours worked in the course of the four weeks preceding the introduction of short time. The amount of the basic allowance will in future correspond to 50 per cent. of the difference between the actual earnings and five-sixths of what the worker would have earned if he had worked full time. For each person dependent on the worker, the amount of the allowance is increased by 10 per cent. of the difference, provided that the total may not exceed five-sixths of normal earnings.

Under Government regulations, overtime in Turkey may not exceed three hours in the day or be worked more than 60 days in the year. Any rest which may be granted after the end of the normal working day and before the beginning of the extra work is included in the overtime. The Ministry of Economy has the right to decide whether the economic requirements of the country call for the working of overtime. In other cases the decision must be taken by the competent authority of the area in which the undertaking applying for permission to work overtime is situated. Permission may be granted for the undertaking as a whole or for certain departments of it only. The working of overtime is subject to the consent of the workers. Where this consent has not been obtained in advance through a clause in the contract of employment or in the internal regulations of the undertaking, it may be given at the time when the application to work overtime is made, in accordance with a procedure to be agreed upon between the employers or their representatives and the workers' delegates.

The application for permission to work overtime must be submitted by the employer or his representatives to the competent authority not later than the day on which the overtime is to begin. The application must contain all necessary details in regard to the grounds for exemption from the ordinary regulations, the extra pay, etc. Permission to work overtime may be granted on one occasion for the whole 60 days or on several occasions for a smaller number of days. The Minister of Economy may grant, in accordance with general or local economic needs, general permission to work overtime for the whole territory of the State or for particular regions or for certain branches of activity only.

The French Decree of October 27, 1939, introduced a system of deduction from overtime pay to meet the expenditure of the National Solidarity Fund. For the application of the system to building and public works, in which collective suspensions of work may be brought about by bad weather, a Decree of February 29 provides that a maximum of five hours in excess of the statutory limit each week must be regarded as compensation for time lost through weather conditions and be paid for at normal rates. It follows (*Industrial and Labour Information* says) that the 40 per cent. deduction does not apply to the remuneration for these five hours. The district labour inspectors are to determine the methods of application of the new Decree, for each department or region, after consultation with the employers' and workers' organisations.

In the course of a speech in the Chamber of Deputies on the employment situation in France since the war, the Minister of Labour emphasised that unemployed typists and shopgirls must be made to understand that their professions are closed to them for the duration of the war and that they must become workers in the national defence industries. Owing to the advances made in technical matters and industrial hygiene, the occupation of a worker or skilled worker in aircraft factories, for instance, is no longer too arduous for a woman of normal health and strength. In a letter to the President of the French General Confederation of Employers the Minister of Labour asked employers to give priority, other things being equal, to wives of mobilised men and to unemployed women. According to the Ministry's instructions to the establishments, the wives of mobilised men must, however, be replaced in undertakings by other women workers in cases where their husbands are brought back to the factory under special exemption permits. Women thus replaced should be held in reserve to meet later needs.

In order to discover whether a shortage of skilled labour impended, the United States National Industrial Board recently asked numerous representative companies, mainly in the metal-working trades, whether, as yet, they had found it impossible to secure the necessary skilled labour. Of 180 companies replying, 44 per cent. stated that they were already unable to secure certain types of craftsmen needed, while the remaining 56 per cent. had been able, so far, to fill their needs. In answer to a question whether any substantial increase in industrial activity would create a serious situation, about 68 per cent. of the replying companies stated that this was certain, and a further 15 per cent. that it was probable. Thus, over 80 per cent. of the companies feared that the available supply of skilled labour was hardly more than adequate for present needs. The great majority of actual shortages reported were in occupations in the metal trades; those outside the metal trades were in woodworking and in branches of the textile industry.

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FORTY YEARS' DEVELOPMENT IN MECHANICAL ENGINEERING PLANT FOR POWER STATIONS.*

By SIR LEONARD PEARCE, C.B.E., D.Sc.

(*Continued from page* 399.)

IN dealing with the general question of heat cycles I have attempted to illustrate the effect on efficiency of increasing steam pressures and temperatures, and have shown the results which have been obtained in a large number of representative stations. It is, however, interesting to consider the general effect of the various improvements on the supply industry as a whole. In Fig. 31, herewith, are plotted the average fuel consumption of all steam stations, both in this country and in the United States, during the last twenty years. These curves afford ample evidence of the great strides which have been made in reducing the cost of generation. A third curve gives the lowest fuel consumption of any station in this country, and it will be noticed that for some years a figure of less than 1 lb. of fuel per kilowatt-hour has been attained. It is of interest to note, in passing, that but for the economies effected in coal consumption, an increase in production costs would have been inevitable as a result of the substantial advance in the price of coal during recent years.

The change from a multiplicity of small units to a comparatively small number of units of much increased capacity has had a considerable effect on station layouts, both from the point of view of increasing the plant capacity installed on a given site and in the matter of the relative disposition of the components. The Deptford site, about 1895, had a total installed plant capacity of only 4,950 kW; to-day, it has a capacity of 353,750 kW, the latter total including not only the original East station but also the West station, built some ten years ago. At present, with seven turbo-alternators and twenty-two boilers, the capacity of the East station alone is twenty-eight times greater than that of the original seven engines and twenty-four boilers. When extensions were made to the East station subsequently to 1895, a second group of boilers was built above the existing boilers, an arrangement which was adopted in several other stations in the early days with small boiler units, notably at the Lots-road station, London. The present capacity of the Stuart-street station at Manchester, with nine sets and eighteen boilers, is about sixteen times that of the original six engines and twenty-four boilers in 1902.

The layout of plant in older stations, into which units of gradually increasing capacity are installed from time to time, is naturally determined by the space available with the minimum of disturbance to existing plant which is to be retained in service; so that such a station, even in its modern form, cannot be entirely representative of modern practice in the disposition of units. It is necessary, therefore, to consider some of the stations which have been built in recent years in order to appraise the latest tendencies.

In the Dunston "B" station of the North Eastern Electric Supply Company, the Barking "B" station of the County of London Electric Supply Company, and the Battersea station of the London Power Company, representative of modern design, the turbo-alternators are arranged in line, parallel with the centre line of the turbine house; but in the case of Dunston and Barking, the boilers are arranged in houses at right angles to the engine room, whereas at Battersea the boilers are arranged in a single row in a house parallel to the turbine house. The layout of the Deptford West station illustrates another different arrangement, in which the boiler house and turbine house are parallel, the axes of the turbines being arranged at right angles to the axis of the turbine room.

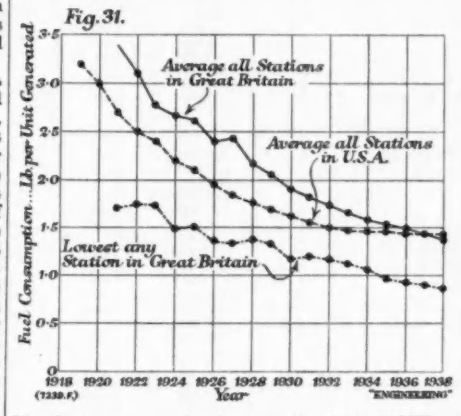
The plant layout for a new station is determined by a great number of considerations, such as the capacity required per unit of site area, and the relative locations of circulating-water supplies, point of coal entry, and point of exit for the transmission mains, and it is not possible to standardise any particular layout. An interesting scheme, which has been adopted in a few stations in the United States, is the installation of the boiler and turbine plant in a single building without any dividing wall. The recent concentration of attention on the question of fire risks, largely in connection with air-raid precautions, is likely to have a considerable effect on the design of new stations, and it is indeed an unhappy reflection that, in these days of so-called highly-developed civilisation, we should have to make pure technical development subservient to such considerations.

The main trend appears to be in the direction of a greater number of stations of a capacity limited to some 250,000 kW—in other words, decentralisation; the separation of switch houses from the main power-station buildings, where practicable; and the division of the component parts of the plant into separate sections, so that damage to any one part may have the minimum effect on the remainder.

While these steps are due to *force majeure*, I am convinced that, from considerations of efficiency, and capital and running costs, they will prevent the steady decrease in the cost of generation of electricity which would obtain if present normal practice were allowed to proceed. It is begging the question to claim, as I have seen done, that this multiplicity of smaller stations can be as efficient as larger base-load stations, simply on the score that the individual plant component efficiencies can be as good. In this connection it is fitting to refer to the utility of the National Grid, which, by reason of the interconnections afforded, should go far to ensure continuity of supplies in areas otherwise dependent upon local generating stations.

In the earlier part of this lecture I referred to turbo-alternator plants of various sizes, and it will be recalled that these covered a range from the 350-kW sets at

Fig. 31.



Manchester-square, London, to the 105,000-kW set at Battersea "B." Probably the most commonly used sizes in this country are those shown in Table VII, herewith.

The size of unit adopted depends on the magnitude of the load on the system, the annual increment of load, and the characteristics of the load curve. Present-day practice appears to favour the 3,000-r.p.m., 30,000-kW maximum continuous rating for extensions to stations of medium size, and to standardise 60,000-kW machines as the next larger size. For the very large base-load stations in this country, turbo units of 75,000 kW and 100,000 kW have been adopted, but there are definite limits to the use of plants of this capacity.

TABLE VII.—*Sizes of Turbo-Alternator Plants.*

Normal Economic Rating. kW.	Maximum Continuous Rating. kW.
10,000	12,500
15,000	18,750
20,000	25,000
24,000	30,000
28,000	35,000
40,000	50,000

In the United States of America there is a leaning towards a somewhat larger unit, for, in addition to the well-known 208,000-kW set at State Line, Illinois, there are quite a number of 150,000-kW to 160,000-kW units in service in that country. In Table VIII, on page 424, is given a representative list of large turbo-alternators installed or on order in this country, in the United States, and on the Continent. Multi-cylinder machines are standard practice for modern power-station developments on account of the improved efficiency which they give, although there are certain notable examples of large-capacity single-cylinder turbines to be found in the United States. In general, an increase in the size of unit is accompanied by a decrease in capital cost, weight, and space per kilowatt, and in Table IX, on page 425, some particulars are given of eleven turbo-alternators ranging from 350 kW to the largest unit—105,000 kW—installed in this country.* During the twelve months from April, 1937, to March, 1938, the 105,000-kW set at Battersea generated 618,686,500 units of electricity, corresponding to 70½ per cent. of the maximum possible. Exclusive of the period that the machine was shut down for routine inspections, it has generated a total of 2,075,962,500 units in forty-four months, this being 64¾ per cent. of the maximum possible.

Where it is necessary to reduce floor space to the very minimum, the arrangement known as steeple-compounding is adopted. In this, the high-pressure cylinder is built above the low-pressure cylinder. This may perhaps be considered as the modern equivalent of the old vertical Curtis turbo-alternators, many examples of which were installed by Messrs. The British Thomson-Houston Company in this country in the early days of power-station developments.

Among other interesting and recent additions to the power-station plants of this country are the 37,500-kW Brush-Ljungström machines installed at the Southwick station of the Brighton Corporation.* These run at 1,500 r.p.m. and are designed for steam at 650 lb. per square inch and 850 deg. F., with a vacuum of 29 in. The turbine comprises two sets of concentric rings of blading carried on the faces of discs rotating oppositely at 1,500 r.p.m. Each half of the turbine thus drives its own alternator. In the main, therefore, for the greater part of its expansion, the steam is expanded in a radial direction and finally passes through a limited number of stages in an axial direction—the blading for which is secured to the same discs. The cylinder casing is in no part subjected to high pressures and temperatures. The main features which distinguish this design of turbine are the saving in weight and space, and ease of starting due to the absence of the high temperatures associated with high-pressure casings.

One of the most interesting developments in recent steam-turbine design has been the increase in capacity of direct-driven high-speed units, namely, the 3,000-r.p.m., 50-cycle sets in this country, and the 3,600-r.p.m., 60-cycle sets in the United States and elsewhere. The main advantages of the high-speed machine are the savings in weight and space. One of the first machines of this capacity ordered in this country was the General Electric 30,000-kW 3,000-r.p.m. set for the Lombard-road station of the Battersea Corporation, which was put into commercial service in December, 1930. This machine is designed for steam at 300 lb. per square inch, and 750 deg. F., with a vacuum of 29 in. (barometer 30 in.), and is arranged for three-stage feed heating to 300 deg. F. The largest 3,000-r.p.m. machines in operation are the two 40,000-kW English-Electric sets in the Ferrybridge station of the Yorkshire Electric Company. The units are of the two-cylinder impulse-reaction type with a double-flow low-pressure cylinder, and are designed for steam at 600 lb. per square inch and 850 deg. F., and a vacuum of 28·8 in. (barometer 30 in.). An order has recently been placed for two 60,000-kW, 3,000-r.p.m., two-cylinder sets for the Littlebrook station of the Kent Electric Power Company, which are designed for a steam pressure of 1,235 lb. per square inch and 825 deg. F. temperature, and will incorporate reheating between the high-pressure and low-pressure cylinders.

In the United States, the largest high-speed unit is the 3,600-r.p.m., 60,000-kW "topping" unit for the Windsor station of the Ohio Power Company. This machine is designed for steam at 1,250 lb. per square inch and 925 deg. F. and exhausts against a back pressure of 235 lb. per square inch gauge, the exhaust steam being used in existing low-pressure turbines. On the Continent, the largest unit is the Siemens 3,000-r.p.m., 60,000-kW quadruple-flow set in the Schelle station of the Société Générale de Production d'Electricité Interescaut. This three-cylinder machine is designed for steam at 610 lb. per square inch and 840 deg. F. There are at present in service or under construction in this country no less than eighty machines of 25,000-kW capacity and above, running at 3,000 r.p.m.

In some instances it is found advisable to use both high- and medium-speed units for a single plant, where of the two-line or two-axis type, particularly when designed for extra high-pressures. In this connection, reference has already been made to the Battersea "B" plant. As will be seen from Table IX, on page 425, the 16,000-kW primary set, operating with steam at 1,350 lb. per square inch and 950 deg. F., runs at 3,000 r.p.m.; while the 84,000-kW secondary set, using steam at 600 lb. per square inch, is designed for 1,500 r.p.m., its size precluding the use of the higher speed. The complete unit is thus designed to deliver an output of 100,000 kW continuously at the terminals of the alternators when generating three-phase electrical energy at a pressure of 11,000 volts. Another interesting example of high-speed, two-axis machines is the plant recently installed at the Brimsdown "A" station of the North Metropolitan Power Company. Both the two-cylinder, 19,000-kW primary turbine (taking steam at 1,900 lb. per square inch and 930 deg. F.) and the two-cylinder 34,000-kW secondary turbine (operating with steam at 200 lb. per square inch and 810 deg. F. after reheating) run at 3,000 r.p.m.

* The 26th Thomas Hawksley Lecture, delivered before the Institution of Mechanical Engineers, in London, on Friday, January 19, 1940. Abridged.

* See ENGINEERING, vol. 141, page 53, *et seq.* (1936).

* See ENGINEERING, vol. 147, page 587 (1939).

MECHANICAL ENGINEERING IN POWER STATIONS.

TABLE VIII.—LARGE TURBO-ALTERNATOR PLANTS.

Date.	Station.	Operating Company.	No. of Machines.	Capacity. kW.	Speed. R.p.m.	Steam Pressure. Lb. per sq. in.	Steam Temperature. Deg. F.	Final Feed Temperature. Deg. F.	Vacuum. In. of Mercury.	No. of Cylinders.
	Great Britain.									
1933	Battersea "A"	London Power Co.	1	105,000	1,500	600	850	355	29·1	3
1937	Battersea "B"	London Power Co.	1	100,000	{3,000 / 1,500}	1,350	950	400	29·1	3
1930–5–7	Barking "B"	County of London Electric Supply Co.	4	75,000	1,500	600	800	340	29·0	3
1928	Battersea "A"	London Power Co.	2	69,000	1,500	570	800	340	29·1	3
1932–6–9	Fulham	Fulham Borough Council	4	60,000	1,500	600	800	358	29·0	2
1936	Littlebrook	Kent Electric Power Co.	1	60,000	1,500	600	800	340	29·0	
1938–9	Littlebrook	Kent Electric Power Co.	2	60,000	3,000	1,235	825			2
1938	Hams Hall "B"	Birmingham Corporation	2	53,500	1,500	650	825	340	28·5	
1938	Brimsdown "B"	North Metropolitan Power Co.	1	53,000	3,000	1,900	930	361	28·5	
1935	Brimsdown "A"	North Metropolitan Power Co.	1	53,000	3,000	1,900	930	361	28·5	{H.P. 2 / L.P. 2}
1935–6	Kearsley	Lancashire Electric Power Co.	2	51,600	1,500	600	800	280	28·75	2
1936	Clarence Dock 2	Liverpool Corporation	2	51,500	1,500	600	800	342	29·0	2
1929–30	Clarence Dock 1	Liverpool Corporation	2	51,500	1,500	400	725	300	29·0	2
1935	Barton	Manchester Corporation	1	51,500	1,500	350	825	310	28·8	2
1934–6	Hams Hall "A"	Birmingham Corporation	3	51,500	1,500	350	730	306	28·0	2
1928–36	Portishead	Bristol Corporation	2	51,250	1,500	300	800	307	29·0	
1936–8	Blackburn Meadows	Sheffield Corporation	2	50,000	1,500	570	825	265	28·0	
1935	Dalmarnock	Glasgow Corporation	2	50,000	1,500	600	825	320	29·0	2
1936	Deptford West	London Power Co.	1	50,000	1,500	350	750	250	29·1	
1930–7	Dunston "B"	North Eastern Electric Supply Co.	4	50,000	1,500	600	800	319	29·0	
1936–7	Ironbridge	West Midlands Joint Electricity Authority	4	50,000	1,500	375	750	315	28·9	2
	United States of America.									
1929	State Line	Chicago and District Gas and Electric Co.	1	208,000	1,800	600	730	415–491	29·3	3
1930	Hell Gate	New York Edison Co.	1	165,000	1,800	265	700			4
1932	Hudson Avenue	Brooklyn Edison Co.	2	165,000	1,800	400	735	270	29·0	2
1924	Philo	Ohio Power Co.	1	165,000	1,800	600	725	300		3
1935	Richmond	Philadelphia Electricity Co.	1	165,000	1,800	375	825	312	29·0	2
1929	East River	New York Edison Co.	1	160,000	1,500	376	700			2
1929	Hell Gate	New York Edison Co.	1	160,000	1,800–1,200	265	610			2
1938	State Line	Chicago and District Gas and Electric Co.	1	150,000*	1,800	1,200	832			3
	Waukegan	Public Service Co., Northern Illinois	2	115,000	1,800	625	750			2
1930–1	Hudson Avenue	Brooklyn Edison Co.	1	110,000	1,800	400	730	270	29·0	2
1931–6–9	River Rouge	Ford Motor Co.	3	110,000*	1,800	1,200	750–900	406	29·0	2
1931–41	Powerton	Super Power Co. of Illinois	3	105,000	1,800	600	725			3
	Burlington	Public Service Corporation, New Jersey	1	100,000						
1928	Crawford	Commonwealth Edison Co.	1	100,000	1,800	550	725			
	Continental.									
	Zschornewitz	Reichselektrowerke A.G.	2	85,000	1,500	200	680			3
	Klingenberg	B.E.W.A.G.	3	80,000	1,500	462	752			3
	St. Denis	Société d'Electricité de Paris	1	60,000	3,000	835	932	361	28·9	
	Schelle	Société Générale de Production d'Electricité Interescaut	1	60,000	3,000	610	840–850			3
	Karnap	Rheinisch-Westfalisches Elektrizitätswerk A.G.	4	55,000	3,000	1,200	932	374	28·02	3
	Arrighi	Union d'Electricité de Paris	4	55,000	1,500	497	797	284	28·8	3
	Goldenbergwerk	Rheinisch-Westfalisches	4	50,000	1,000	171	662		28·2	1
	Goldenbergwerk	Elektrizitätswerk A.G.	3	50,000	1,500	171	662		28·2	1
	Oderkraftwerk	Markisches Elektrizitätswerk A.G.	3	50,000	3,000	1,564	887	428	28·8	2
	Finkenheerd	Markisches Elektrizitätswerk A.G.	1	50,000	3,000	500	815	302	28·8	2
	Mollis	Aktiengesellschaft Sächsische Werke	1	50,000	3,000	924	896	266	28·35	2
	St. Denis	Societé d'Electricité de Paris	3	50,000	3,000	850	870	356	29·04	3
	Västeras	Sweden	1	50,000	1,500	285	840			
	Gennevilliers	Union d'Electricité de Paris	2	50,000	1,500	312	662			
	Dnieprodzerzhinski	Russia	1	50,000						
		Moscow Maschinoimport A	1	50,000	3,000	435	797	320	28·55	2
		Moscow Maschinoimport B	2	50,000	3,000	435	797	320	28·55	2
	Espenhain	Aktiengesellschaft Sächsische Werke	3	49,000	3,000	924	896	266	28·35	2
	Lunen	Steinkohlen Elektrizitäts A.G.	3	45,000	3,000	924	914	392	28·8	2
	Chorzow	Slaskie Zaklady Elektryczne Spolka Akcyjna	1	45,000	3,000	796	896	347	28·08	1
	Galileistraat	Municipality of Rotterdam	2	42,000		356	752			
	Gennevilliers	Union d'Electricité de Paris	6	40,000		312	662			

* Hydrogen-cooled generator.

In this instance, the size of the secondary set was such that the higher speed could be used.

Of the two main types of governing—throttle control and nozzle control—the former is more generally adopted for units which operate principally at their designed economic load. Nozzle control is used for machines subject to wide variations in load and gives a flatter steam-consumption curve, though this advantage is not so noticeable in the case of large multi-cylinder machines. There is little to choose between the two systems on the score of overall efficiency.

The effect of throttling at lower loads is to move the condition curve over to the right of the total heat-entropy chart, so that the lower stages operate in a region of greater dryness. This is an advantage both from the point of view of efficiency and the prevention of blading erosion. With throttle governing, overloads are met by bypassing a portion of the steam round some of the early stages, whereas with nozzle governing they are met by providing an additional group of nozzles. It follows that, with throttle governing, the maximum moisture content is obtained at economic load, and the moisture content is less both at overload and partial loads; whereas, with nozzle governing, the moisture content at overload is higher than at economic load and remains substantially the same at partial loads as at economic load.

Marked progress is also to be recorded in the relay-controlled oil systems developed for the operation and regulation of governor valves. Modern operating conditions have necessitated an increase in the actuating forces as well as a more rapid response. The provision for extra high-pressure "topping" units superimposed on existing low-pressure plants has necessitated special pressure-response controls to maintain a constant back pressure, and this has somewhat complicated the governing arrangements required.

Another development of recent years, more particularly in the case of large machines, has been the provision of load-limiting devices to prevent the overloading of individual machines during times of possible disturbance to the system. Other developments worthy of note are the fitting of barring gears to the larger sizes of turbines, and the installation of high-pressure oil jacking pumps, all of which are very useful adjuncts to turbine equipment.

Considerations of a typical condition curve for a turbine, traced on a total heat-entropy diagram, will show that increasing the initial steam pressure with a given constant steam temperature increases the moisture in the exhaust; increasing the initial steam temperature with a given constant steam pressure decreases the moisture in the exhaust; and increasing the vacuum at the exhaust increases the moisture. As the turbine efficiency is increased, the moisture in the exhaust increases for given steam conditions. The introduction of multi-stage bled-steam feed heating is of assistance in reducing the wetness in the exhaust, as a certain amount of the moisture formed can be carried away through the low-pressure bled-steam connections.

The limiting final moisture content which is usually considered advisable is about 12 per cent. to 13 per cent., and it follows that the maximum initial steam pressure is determined by the steam temperature which it is proposed to use. Taking a turbine efficiency of the order of 80 per cent. to 82 per cent., a vacuum of 29 in. to 29·1 in. (barometer 30 in.) and a final moisture content of 12 per cent. to 13 per cent., it will be found that the limiting pressures with various initial steam temperatures are generally as shown in Table X, below.

Table X.—*Limiting Steam Pressures with Various Steam Temperatures.*

Steam Temperature. Deg. F.	Steam Pressure. Lb. per sq. in. gauge.
750	580
800	750
850	950
900	1,200
950	1,500
1,000	1,900

Modern designs of turbo-alternators include special drainage belts in the last stages, into which the minute droplets of water are flung by centrifugal action and are drained away to the main condenser. In the case of machines working with very high moisture contents, it is usual to protect the leading edge of the last few rows of blades with a strip of specially-hardened material.

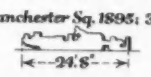
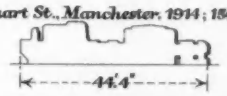
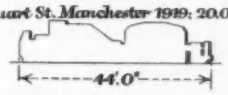
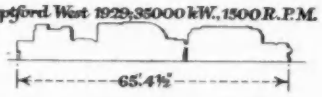
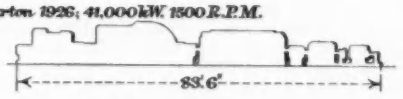
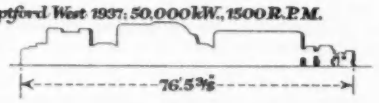
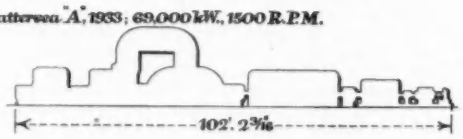
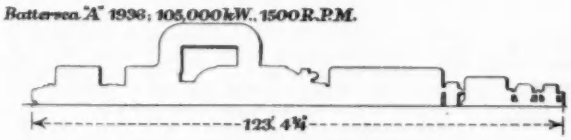
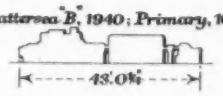
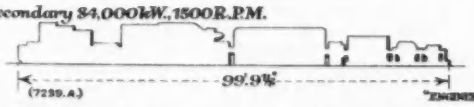
(To be continued.)

Australian-Built Locomotives for N.S.W. Railways: Erratum.—We gave, on page 366, *ante*, some brief particulars of five Pacific-type locomotives, which are being built for the New South Wales Government Railways by the Clyde Engineering Company, Granville, N.S.W. We regret that an error was made in stating the piston stroke. The correct stroke is 21½ in.

MECHANICAL ENGINEERING IN POWER STATIONS.

(*For Description, see Page* 423).

TABLE IX.—COMPARISON OF TURBO-ALTERNATORS.

Unit.	Steam Conditions.		No. of Stages.	Ratios.	
	Pressure. Lb. per sq. in. Gauge.	Temperature. Deg. F.		kW per Sq. Ft. Floor Area.	Lb. Weight per kW.
Manchester Sq. 1895; 350 kW., 3000 R.P.M. 	150	366 (dry sat.)	77	3·55	128
Stuart St., Manchester, 1907; 5000 kW., 1000 R.P.M.	190	500	50	10·1	71·9
Stuart St., Manchester, 1914; 15000 kW., 1000 R.P.M. 	190	530	14	25·1	42·0
Stuart St. Manchester 1919; 20,000 kW. 1500 R.P.M. 	200	600	23	30·8	28·6
Deptford West 1929; 35000 kW., 1500 R.P.M. 	350	750	39	30·4	22·1
Barton 1926; 41,000 kW. 1500 R.P.M. 	350	700	41	24·8	24·1
Deptford West 1937; 50,000 kW., 1500 R.P.M. 	350	750	41	35·4	22·4
Battersea "A" 1933; 69,000 kW., 1500 R.P.M. 	570	800	47	37·0	19·5
Battersea "A" 1936; 105,000 kW., 1500 R.P.M. 	600	850	44	51·6	16·0
Battersea "B" 1940; Primary, 16000 kW., 3000 R.P.M. 	1,350	950	12	41·4	14·5
Secondary 84,000 kW., 1500 R.P.M. 	600	750–850	43		

(7239.A.) "ENGINEERING"

ELECTROLYTIC CORROSION OF SHIP STRUCTURES.*

By J. H. PATERSON, D.Sc.

OWING to the complexity of the problems connected with the rusting and corrosion of iron and steel, it is not possible in a paper of this type to go into them in detail. It is therefore intended to deal with the theoretical side of the question in the simplest and broadest possible manner. It is necessary to distinguish between general corrosive attack, in which large areas of exposed steel surfaces are subjected to more or less uniform deterioration, and localised corrosion, in which small local areas are the subject of attack, the remainder of the metal surface remaining more or less unaffected. The general attack will be referred to as "rusting" and the localised attack as "corrosion." It would save considerable confusion if some standard nomenclature were adopted which would distinguish between the two processes. The rusting of iron and steel may be defined as the deterioration of these metals due to chemical action on them of the surrounding media—generally air or water, or both. The products of the corrosion of iron are normally two oxides of iron, namely, ferrous hydroxide, which is black or green, and ferric hydroxide, which is red. The mixture of these oxides, iron rust, usually contains small quantities of other materials, such as carbon, lime, magnesia, silica and sulphur, when the rust is formed in contaminated air or in impure waters. Modern theories assume that the forces behind the chemical reactions involved are electro-chemical, and that the existence of electrical potential, varying in magnitude with the metal and the surrounding medium, is essential.

The following facts must be borne in mind:—(1) Rust formation requires both water and oxygen; as all natural waters contain oxygen in solution, rust will invariably take place when the metal is submerged. (2) Rusting is more rapid in acids than in neutral atmospheres or solutions, and is least rapid in alkaline solutions. (3) Films of solid or gas are usually formed on the surface of the metal, and, if adherent enough, act as a deterrent to further rusting. (4) If the protective films or other protecting medium, such as paint, are removed locally by scratching or rubbing, localised corrosion will generally be much more rapid than the rate of rusting which would take place if the whole surface were exposed to attack. (5) Local dissimilarities in the composition of iron and steel, or iron in contact with other metals, will set up local corrosion. Local strains in the iron will have a similar effect.

Iron exposed to pure moist air rapidly acquires a thin and adherent, but mechanically weak, coating of iron oxides which serve as a protection against further chemical action. If the air contains acid substances, such as sulphur dioxide, rusting takes place at a much higher rate; and if particles of dust, particularly carbon or soot, and many other chemical substances derived from the soil or from burning coal, are present, the rate is accelerated to an even greater extent. Fig. 1, on page 426, from Dr. Hudson's book on corrosion,* shows this very clearly, and in Dr. Vernon's original work the following conclusions are arrived at:—(*a*) In comparatively dry air, with a relative humidity of less than about 70 per cent., very little rusting occurs, whether the atmosphere is polluted or not. In atmospheres contaminated with sulphur dioxide, there is a pronounced increase in the rate of rusting when the relative humidity rises above about 80 per cent. (*b*) The rate of rusting in pure moist air is comparatively small. (*c*) Minute quantities of solid particles, such as ammonium sulphate, which are normal constituents of the dust blown on to metals in service, cause a marked increase in the rate of rusting.

Rusting can take place when the metal is wholly or partly submerged in water, just as in air. The basic phenomena are similar, but it is easier in explaining marine corrosion to deal with under-water corrosion only. When iron is placed in water or in a salt solution, particles of iron with a positive charge (iron ions) tend to go into solution, the iron thus acquiring a negative charge. As the solution must remain electrically neutral some other positive ion must come out of solution before this can happen. The water molecules H O H each contain one positive and one negative OH ion, so that if the water were to split up in part and the positive H ions were freed, similar positive ions could go into the solution. This is what actually happens; a minute amount of iron goes into the solution and a similar amount of hydrogen is liberated, forming a closely adhering film on the surface which soon obstructs the further passage of the ion into the solution to such an extent as to stop the reaction altogether. If rusting is to take place then, this film of hydrogen must be removed all the time the corrosion is taking place. This is done by the oxygen dissolved in the water, and as long as oxygen is available the hydrogen film will continue to be destroyed and electrical forces will continue to drive iron ions into solution. Some of these iron ions are converted by the water into rust.

Some substances, notably acids, tend to increase the supply of hydrogen ions in the water. Other substances, notably alkaline materials, have the reverse effect by increasing the negative OH ions. The concentration of hydrogen ions is expressed by the "*p*H value," and as this is of growing importance and is little understood by the layman, a short explanation may be given.†

Pure water is very slightly decomposed into hydrogen ions and hydroxide ions. The product of these two quantities is always a constant in water or in any aqueous solution, and the value is approximately 10^{-14} at room temperature. Hence, if the concentration of the hydrogen ions is 10^{-4} per litre, the concentration of the hydroxide ions is 10^{-10}. The acid properties of solutions are due entirely to hydrogen ions, and the alkaline properties to hydroxide ions. When these ions are present in equal amounts, the concentration of each is 10^{-7} and the solution is neutral. This would be the case in pure water. Acid solutions are those which have a concentration of hydrogen ions greater than 10^{-7}. Alkaline solutions are those with hydroxide-ion concentrations greater than 10^{-7}. For convenience, this is expressed as the log of 1/hydrogen-ion concentration, which is given the symbol *p*H. Thus pure neutral water has a *p*H of 7; acids, a *p*H value of less than 7; and alkalies a *p*H of more than 7. The relationship between hydrogen-ion and hydroxide-ion concentration and *p*H is shown in Table I, on page 426.

* Paper read before the Institution of Engineers and Shipbuilders in Scotland, in Glasgow, on April 9, 1940. Abridged.

* *The Corrosion of Iron and Steel*, by J. C. Hudson, D.Sc. London: Chapman and Hall, Limited. 1940.

† *Corrosion Causes and Prevention*, by F. N. Speller, D.Sc. New York: McGraw-Hill Book Company. 1935.

Fig. 2, on this page, shows the relative effect of *p*H value on the corrosion of steel in water free from salts or impurity which may form protective coatings. This

Table I.—*Hydrogen and Hydroxide-Ion Concentration and pH.*

Nature of Solution.	Concentration of Hydrogen and Hydroxide Ions. Gm. Equivalent per Litre.	*p*H Value.
Acid (hydrogen ions predominate).	1·0	0
	0·1	1
	0·01	2
	0·001 Hydrogen ions (H^+).	3
	0·0001	4
	0·00001	5
	0·000001	6
Neutral (hydrogen and hydroxide ions present in equal quantity).	Hydrogen (H^+) and	7
	0·0000001 Hydroxide (OH^-) ions.	
Alkaline (hydroxide ions predominate).	0·000001	8
	0·00001	9
	0·0001	10
	0·001 Hydroxide ions (OH^-).	11
	0·01	12
	0·1	13
	1·0	14

diagram can be divided into three zones, each with a different range of *p*H. The principal factors which govern the rate of corrosion within each zone are shown below :—

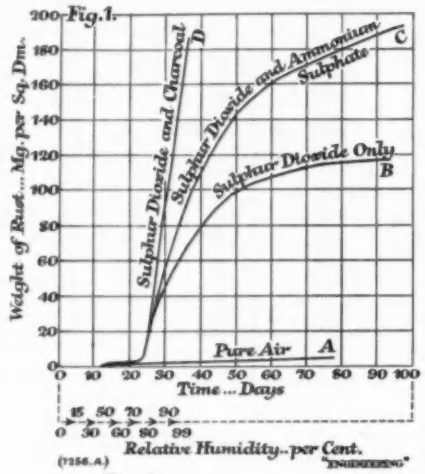
Alkaline Zone. (*p*H greater than 10), Corrosion Slow.	Neutral Zone. (*p*H from 4·3 to 10), Corrosion Medium.	Acid Zone. (*p*H less than 4·3), Corrosion Rapid.
Protective films	Oxygen concentration.	Hydrogen-ion concentration.
Oxygen concentration.	Protective films	Composition of metal.
Composition of metal.	Hydrogen-ion concentration.	Oxygen concentration.
Hydrogen-ion concentration.	Composition of metal	Protective films.
Metal-ion concentration.	Metal-ion concentration.	

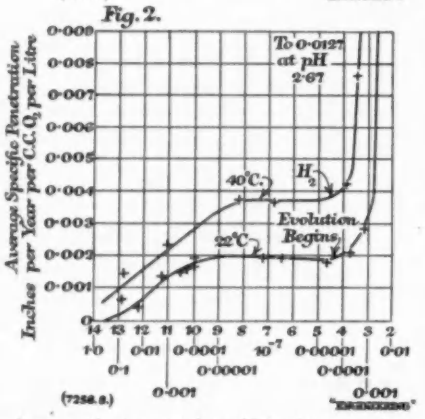
The *p*H value of water is of the greatest importance as most fitting-out basins in or near rivers usually contain dissolved materials foreign to normal water supplies. Sewage at certain stages of decomposition may have a *p*H value of less than 4·5, and if any part of a ship's hull is unprotected, through scratching or defective painting, it will be the subject of rapid corrosion, partly due to the acid water and partly due to the accelerated effects of local exposure. In at least one case investigated by the author, the *p*H value of running water in the stream was about 7, whereas the same water, on standing for 48 hours, developed a *p*H value in the neighbourhood of 3·9. This still-water effect was produced by the angle at which the ship was lying to the shore, there being on the inner side of the ship an area free from eddies. The readings were taken during an investigation into the abnormal corrosion of rivet heads in the rudder plates of a new ship. The corrosion was stopped by turning the ship so that the stern was up stream, and bringing the ship more nearly parallel with the jetty, so that no places in which water could stand for any length of time were possible. This is probably an extreme case, but it illustrates the value of knowing the *p*H values of water in which unprotected or partly protected ships' hulls are floating.

It has happened occasionally that strong mineral acids get into the bilges of ships and the effects are worth noting; though the local corrosion is of a much more violent nature, it is typical of the ordinary types of corrosion which take place more slowly. Two ships, the Norhilda and the Querida, came over in the early part of the last war from the United States carrying strong sulphuric acid in steel drums. A number of drums were damaged owing to faulty stowage, and both ships arrived in the Thames with large quantities of free sulphuric acid floating about in them. This acid also contained traces of nitric acid and was diluted with salt water, making it into a most violent corrosion medium, probably without precedent in the history of steel shipbuilding. The bilge pumps on both ships were completely useless, the packings having been eaten out, and the attack on the ships' hulls was so violent that the fizzing noise produced by the escape of hydrogen could be heard at almost any part of the ship. Both ships were saved, but, where the acid had been, practically all the rivet heads were eaten away. Here and there the edges of angle bars had been attacked, and where parts of the structure had been subjected to cold bending there were signs of pitting along the strained parts.

Some sulphur-bearing materials, such as coal containing iron pyrites (iron sulphide) and fuel oil containing sulphur, can have the sulphur, under suitable conditions, oxidised to sulphuric acid. These conditions are generally supplied by the presence of moisture and the free access of air. The sulphuric acid thus developed, though it may be only small in quantity, results in the development on the plates of local spots having a *p*H value well within the danger area. Owing to the greater rapidity of oxidation, ships in hot climates are more liable to this form of attack than ships trading in more temperate climates.

It has been pointed out that iron placed in water tends to take a negative charge, and a voltage difference is set up between the metal and its ions in the solution. If hydrogen be taken as zero, the metals can be placed in a definite "electro-chemical series," each metal displacing from a solution those below it. This is not strictly true, but is enough for general purposes. Table II, below, shows the single-pole potentials for some common metals. This means that, if a metal at the top of the series were in contact with one nearer





the bottom, the top metal would tend to corrode, and in doing so protect the one below it. The practice of putting zinc rings between bronze or copper outlets and the steel hull of a ship is a good example of this type of "protection." The use of zinc pads on steel frames and other parts of a ship in which bronze propellers are used is another example, although it

Table II.—*Single-Pole Potentials for Common Metals.*

Element.	Reference Ion.	Potential in Volts.
Zinc	Zn^{++}	$-0·761_8$
Iron	Fe^{++}	$-0·44_1$
Cadmium	Cd^{++}	$-0·401_5$
Nickel	Ni^{++}	$-0·23_1$
Tin	Sn^{++}	$-0·13_6$
Lead	Pb^{++}	$-0·12_5$
Iron	Fe^{+++}	$-0·04_5$ (c)
Hydrogen	H^+	0·000
Copper	Cu^{++}	$+0·344_1$
Copper	Cu^+	$+0·522$ (d)
Silver	Ag^+	$+0·797_8$
Gold	Au^{+++}	$+1·3_6$

seems likely that the zinc in this instance is of more value in decreasing local corrosion due to the propeller wash than that due to the bronze propeller.

At this point it is necessary to deal with another phase of the electro-chemical phenomena which enter into corrosion. If dissimilar metals such as iron and copper are in contact under a conducting solution such as impure or salt water, a small electrolytic cell will be formed. As current begins to flow, the *p*H value of the layer of water over the iron falls to a low figure and comes well within the area on the *p*H curve in which rapid attack will take place. The iron is dissolved, and if the solution contains salt, a soluble iron chloride will be formed which will float away and leave a clean surface always ready for a fresh attack. This "electrolytic corrosion" is responsible for a great deal of pitting in ships' plates. Although mill scale is not a metal it acts like a metal that is more electro-positive than iron, and where a particle of mill scale is in close contact with iron and has free access to sea water, a small area over the iron will be formed with a low *p*H value, with a resulting rapid attack. The only remedy for this trouble is the complete removal of the scale.

Research has shown that a variation in the composition of iron or steel within the same body of the metal can set up differences of potential when it is immersed in water; thus in a steel in which the carbon content is not evenly distributed, the higher-carbon areas will be anodic to the lower-carbon areas. This means that, over the higher-carbon areas, the water solution will have a lower *p*H value, and corrosion will take place more rapidly at these points. This is well exemplified in the corrosive attack on the points of rivets made from rimmed steel. It has been shown that steel subjected to stress and in a condition of strain, is anodic to less strained steel alongside it. Plates which have been subjected to cold bending, and are under water in an unprotected condition, are liable to have an area of low *p*H value along the lines of maximum strain. Similarly, rivets closed at a low enough temperature to retain strain will be anodic to the plates surrounding them. It appears certain that, the higher the carbon content of the steel, and therefore the greater the strain it retains under cold-working conditions, the greater will be the difference in potential between the strained and unstrained portions. This means that, in a badly segregated steel that has been subjected to cold working, there may be differences of potential between areas in addition to the potential differences set up by composition differences. When it is remembered that, if this is true, mild-steel plates which have been sheared, punched, cold-bent, or hammered have areas of potential corrosion at these points, it is not surprising that wrought-iron plates which have undergone similar treatment do not show anything like the same deterioration due to local corrosion in service.

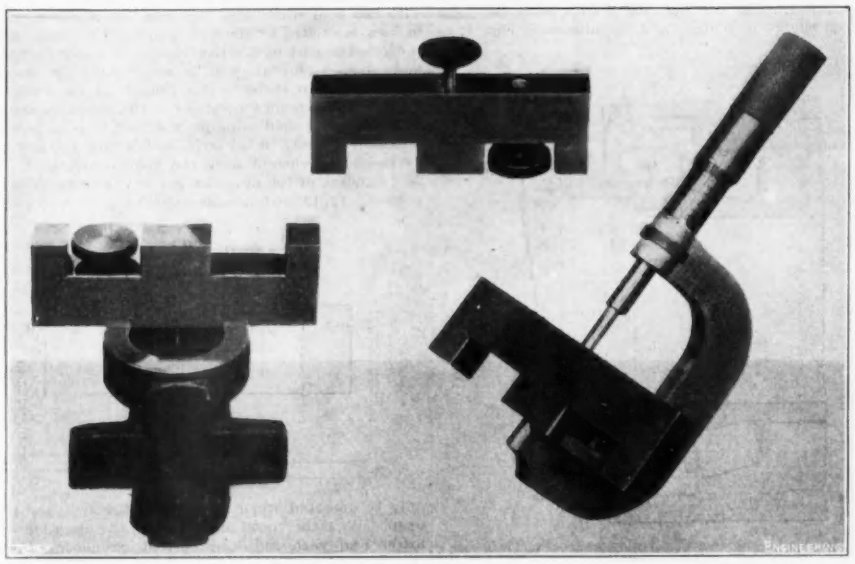
Many theories have been put forward explaining the superior corrosion resistance of some wrought irons, based either on the slag they contain or upon an extremely adherent and thin layer of iron oxide or slag, but it is certain that the large amount of cold work which is to-day done on a higher-carbon steel, as compared with the older methods of construction, is responsible for the greater localised corrosion which is now found in badly-protected ships' structures.

Notch corrosion can play a very important part in the deterioration of ships' structures. The mechanism of this special form of corrosion differs considerably from those already dealt with. It was found, some years ago, that if the oxygen concentration in the solution varied in different places, a difference of potential was set up in the steel between the high-concentration spots and the low-concentration spots. Dr. U. R. Evans showed that areas shielded from oxygen become anodic to the areas which are in contact with solutions richer in oxygen. If so, then, obviously, under suitable conditions, these anodic areas will be the subject of more or less rapid attack. Dr. Evans arrives at the following conclusions :—(1) The effect of restricting the access of oxygen to one part is not to increase the total corrosion of the specimen (at least during the early stages of corrosion), but to concentrate on the non-aerated area the corrosion which would otherwise be spread over the whole surface. (2) Suppose . . . that a small cavity exists in the surface of the metal into which oxygen cannot diffuse quickly. A current will be produced between the unaerated area within the cavity, which will become anodic, and the aerated part of the surface outside, which will be the cathode; soluble salt will be formed at the anodic surface within the cavity, but this will not, of course, interfere with further anodic attack. At the mouth of the cavity, where the soluble metallic salt from the interior mixes with the alkali from the cathodic part outside, hydroxide may be precipitated, but it will not put a stop to the anodic attack proceeding within. Since the rate of attack is determined by the supply of oxygen to the whole surface outside the pit, and since it is all concentrated on the small area within the pit, the rate at which the corrosion bores into the metal will be very great.

A "notch" may be almost any part of a structure into which the surrounding water cannot penetrate quickly and in which it remains perfectly still. Very imperfectly caulked laps between plates are a good example, and improperly filled junctions between plates and angle bars are another. Local corrosion will take place in these partly closed areas at a much greater rate than on a fully exposed surface.

HEIGHT AND DEPTH GAUGE.

MESSRS. CONTINENTAL MACHINES, INC., MINNEAPOLIS, U.S.A.



A great deal has been written about the effect of electric-current leakages on the corrosion of iron and steel structures in contact with water or moist earth. Leakage usually occurs by the passage of current from a badly insulated conductor at a high potential to one at a lower potential, and there is no doubt that a good deal of the rapid corrosion observed on parts of a ship's hull not properly protected by paint has been due to current leakages of this description. Those parts of a ship's hull, for instance, which, owing to the existence of launching structures, get no paint or only the merest dab, have been found to be corroded after only a few days in the water. There is no doubt that in such instances electrolytic corrosion, due to stray currents, is to be suspected, and, indeed, has been known to happen. On the other hand, in numerous instances where corrosion of a more or less serious nature has taken place, it has, without any adequate reason, been put down to the action of stray currents. The whole matter requires a great deal more consideration than has been given to it.

It will be recognised that, in view of the large number of possible causes for the production of the right corrosive conditions, protective media are in the end the only satisfactory solution of the problem. Here, again, however, there is still a good deal of controversy regarding the way in which these media should act, and there are no settled convictions as to the superiority of one method over another. Obviously, galvanising of steelwork is an enormous help in the right direction. For ordinary purposes, however, this is much too expensive and we still have to rely on liquid mixtures, such as paints and bitumen solutions. Dr. Hudson suggests that special investigations should be made into the properties of the various protective compositions by appropriate research bodies, and there is no doubt that a great deal of work could be usefully done in correlating the knowledge already obtained. The only points that can be brought out here are that any protective medium must be impervious to moisture and to oxygen; and that the solid fillers contained in most protective media must not be capable of attack from any external source. It has been found, for instance, that when lime compounds have been used as fillers in tank-top compositions, slightly acid liquid condensates from the cargo or from the coal bunkers have gradually deteriorated the composition and allowed corrosion to take place underneath it.

In view of the very small amount of literature, published in this country dealing specially with corrosion in ship structures, there is an obvious necessity for more special research and exchange of views on this extremely important subject.

ROAD-TRAFFIC SIGNALS.—A new type of traffic light, to take the place of the present ones, has been approved by the Home Office. Instead of the present "cross" marks, the whole of the upper half of the red, amber and green lights will be visible on the new signals. The lights will be bright during the day but will be operated on less power, and therefore dimmer, at night.

DOALL HEIGHT AND DEPTH GAUGE.

THE gauge shown in the accompanying illustration is virtually an ingenious adaptation of the well-known length gauges, since it makes use of a series of accurately finished rods in a wide range of lengths. The rods, however, are inserted for use in the E-shaped block appearing in all three of the views given and are of such a length that the overall dimension of both block and rod gives the readings. The gauge will provide readings between 1 in. and 6 in., different lengths of rod being used for the major steps, the intermediate precise readings being obtained by movement of the rod in the gauge. The instrument is shown in the top view with a fitting on the rod, viz., a sharp-edged disc of a diameter greater than the width of the block. The gauge thus arranged can be used to lay-out parallel lines from a suitable base simply by running it along the work with the edge of the disc bearing on the surface. The distance apart of the lines, or the height of a single line from the base, can be accurately determined by setting the gauge in a caliper or other micrometer, the rod being locked rigidly in position, when the required dimension has been ascertained, by means of the knurled screw seen to the right.

When used for measuring the depth of a hole, otherwise awkward to determine with precision, the gauge is applied as indicated in the bottom left-hand view. This shows only a shallow hole being measured for depth and, in consequence, only a short rod, which is just visible, is employed. A spring in the block ensures that the rod is held in contact with the surface at the bottom of the hole and locking is then effected by the thumbscrew. Clearly, the gauge can also be used for checking the parallelism of external and internal faces by moving it round or over the surface.

The measured depth is read off by the micrometer, as shown in the bottom right-hand view, only a short rod being again illustrated. No addition or subtraction is required in the reading, the maximum overall dimension of the gauge and rod being known. Any dimension from 1 in. to 6 in. can be read in thousandths of an inch, the gauge itself being exactly 1 in. deep. It is hardened and ground and 12 rods are provided. The whole equipment is normally supplied in a velvet-lined leather case. The object of the three legs on one side of the gauge is to give stability to it when measuring, say, the width between parallel surfaces, since the wide base thus provided ensures a truly perpendicular position of the rod, a condition not always obtainable when using an ordinary internal micrometer with two end measuring points. It is understood, of course, that in this case the whole gauge can be inserted between the parallel walls. The Doall height and depth gauge has been recently developed by Messrs. Continental Machines, Incorporated, 1,301, Washington Avenue South, Minneapolis, Minnesota, U.S.A., a firm represented in Great Britain by Messrs. George H. Alexander Machinery, Limited, 82-84, Coleshill-street, Birmingham, 4.

DETERMINATION OF TELLURIUM IN TIN-RICH ALLOYS.

IN a paper presented before the Institute of Metals in 1938, Professor D. Hanson and Dr. W. T. Pell-Walpole stated that experiments had shown that additions of up to 0·1 per cent. of tellurium to pure tin, while only slightly improving its Brinell hardness and tensile strength, imparted to the metal a remarkable capacity for work-hardening and also considerably improved its creep strength, both in the cast and in the rolled conditions. As is always the case with small additions of one metal to another, it is important to be able to ascertain easily and rapidly the exact percentage present, and after conducting a research on the subject, Dr. Pell-Walpole has worked out a convenient method of determining the tellurium in these alloys. The method, which is described in a publication issued by the International Tin Research and Development Council, Fraser-road, Greenford, Middlesex, depends on the fact that when a tin-rich tellurium-tin alloy is heated *in vacuo*, under suitable conditions, the compound tin telluride (TeSn) distills without dissociation. It is stated that the whole of the tellurium present in the alloy can be removed in this manner.

Experiments made to determine the optimum conditions of time and temperature for the distillation process, indicated that heating a sample of the alloy for one hour at 1,000 deg. C., in a vacuum of 0·02 mm. to 0·03 mm. mercury, was satisfactory for alloys containing from 0·05 per cent. to as much as 10 per cent. of tellurium. The procedure finally adopted consists in weighing a 5-gramme sample of the alloy to be analysed into a porcelain combustion boat and placing this in a silica tube, closed at one end and connected at the other end to a vacuum pump. The tube is then evacuated to a pressure of 0·02 mm. to 0·03 mm. mercury, and is placed in a horizontal electric furnace heated to 1,000 deg. C. The tube is left in the furnace for an hour, continuous pumping being maintained to draw the vaporised TeSn to the cooler parts of the system. The evacuated tube is then withdrawn from the furnace and allowed to cool down to room temperature, to prevent oxidation of the tin, before air is admitted. The sample is then removed and weighed a second time, the loss in weight being taken as TeSn, which contains 51·7 per cent. of tellurium by weight. Determinations, in triplicate, were made on a series of 15 alloys containing amounts of tellurium ranging from 0·05 per cent. to 4·5 per cent., and on one alloy containing 10 per cent. of tellurium. The results obtained were generally in agreement to within 0·01 per cent., and in the few instances in which the deviation was greater than this the cause was traced to segregation in the original alloys.

CATALOGUES.

Electrodes.—Messrs. Lincoln Electric Company, Limited, Welwyn Garden City, Herts, have sent us a pamphlet which is the first of a series dealing with their "Fleetweld" electrodes.

Small Rotary Pumps.—We have received from Messrs. Rotherham and Sons, Limited, Coventry, a folder describing various types of pumps for handling oil, petrol, cutting compounds, etc.

Material-Handling Plant.—Messrs. Robert Boby, Limited, Bury St. Edmunds, have sent us a folder describing and illustrating the pneumatic conveying installations and other material-handling plant which they have supplied to various parts of the world.

Electrical Cut-Outs.—Messrs. Crypton Equipment, Limited, North Acton-road, Park Royal, London, N.W.10, have published an illustrated leaflet which describes a new design of automatic battery cut-in and cut-out already supplied in sizes up to 400 amperes for constant-potential battery charging.

Welding and Brazing Compounds.—We have received from Messrs. The Tipweld Manufacturing Company, 173, Newtown-row, Birmingham, 6, a leaflet dealing with their products, Tipweld and Fluxwell, the former being used for tipping and hardening tools in one operation, and the latter for brazing carbide tips.

Domestic Refrigerators.—Messrs. The General Electric Company, Limited, Magnet House, Kingsway, London, W.C.2, have sent us a pamphlet giving particulars of their Coldair electric refrigerators for general domestic use. It is stated that the slow-speed compressor unit supplied with these refrigerators causes no interference with radio reception.

Tapping Machines.—We have received from Messrs. Broadway Engineering Company, Limited, Carlisle-road, Hendon, London, N.W.9, a leaflet describing an ingenious pneumatic, oscillating, tapping machine, manufactured by the L. J. Kaufman Manufacturing Company, Manitowoc, Wisconsin, U.S.A. When dial-set to a predetermined resistance, the tap will free itself should the torque be excessive.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

ABSTRACTS OF SPECIFICATIONS RECENTLY PUBLISHED UNDER THE ACTS OF 1907 TO 1939.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned, the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, etc., of the Communicators are given in italics.

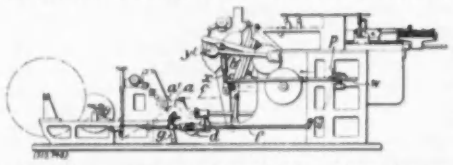
Copies of Specifications may be obtained at the Patent Office Sales Branch, 25, Southampton Buildings, Chancery-lane, London, W.C.2, price 1s. each.

The date of the advertisement of the acceptance of a Complete Specification in each case, is given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

PRINTING AND ALLIED MACHINERY.

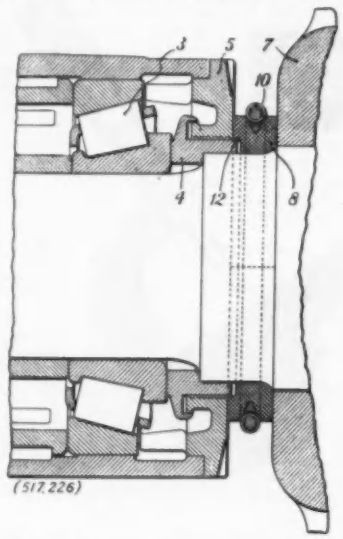
515,748. Printing Duplicate Copies. F. R. Martin, of London. (6 *Figs.*) June 8, 1938.—The machine enables an original print of a form and copies of it in the same or another colour to be printed side by side, and to be delivered so that they can be collated with the originals and duplicates in their proper order. A combined rotary and platen printing machine has an impression cylinder *a* which co-operates with a printing cylinder *a'*, and the bed *b* of the platen is movable. The run of the web of paper through the machine is shown by the chain lines *c*. The mechanism can be set to move the impression cylinder *a* out of the printing position during alternate working cycles. A cam *d* is driven at half speed and reciprocates press into the operative position during those alternate cycles. A cam *d* is driven at half speed and reciprocates a rod *f*. The rod moves a forked arm in engagement with a lever, which rotates an eccentric shaft upon which the impression cylinder is mounted. The rod *f* can be disconnected from the forked arm by withdrawing a pin held in a boss on the arm and engaging an adjustable grooved collar on the rod so that the rotary press can be



set to the operative or inoperative position for any number of working cycles of the machine. The rod *f* is also linked to a double lever *p*, the two parts of which are connected by a withdrawable pin, and which controls a double-ended pawl. As the double lever is oscillated, the ends of the pawl are alternately depressed to engage shoulders on a rod *w*. This rod is connected to the joint of a toggle link *x*, which is, in turn, pin-jointed to an arm on an eccentric shaft *y'*, which controls the range of movement of the bed *b* of the platen press. When the rod *w* is held against movement in the direction of the arrow, the eccentric shaft *y'* is turned to prevent swinging into the printing position during that working cycle of the machine. As the cam is driven at half-speed, the pawl will only operate to throw off the impression during alternate cycles. Thus the rotary press can be set to print or leave blank a portion of the web, the blank part being printed in the platen press as the web is drawn through the combined machine. The printed sheets are slit and cut off, and pass on to a belt, from which they are delivered into trays. (*Accepted December* 13, 1939.)

RAILWAYS AND TRAMWAYS.

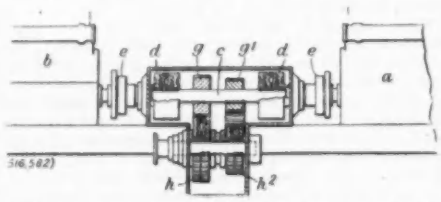
517,226. Packing for Axleboxes. British Timken, Limited, of Birmingham, and E. H. Doughty, of Birmingham. (15 *Figs.*) July 20, 1938.—The invention is a packing for use in connection with the axleboxes of railway locomotives, coaches and wagons. The object is to provide for sealing the ends of an axlebox, to prevent leakage of oil between the stationary and rotating parts, and also to prevent the ingress of steam, water and grit. The axlebox of the locomotive is supported upon the wheel axle through roller bearings 3. The inner end of the axlebox is closed by an annular cover plate 5 closely surrounding the abutment ring 4, a space being left around the axle between the end cover plate and the boss 7 of the wheel. In this space, a packing ring 8 is removably fitted to seal the joint between the cover 5, and the abutment ring 4, so as to prevent the ingress of steam, water or grit. This packing ring 8 is composed of a yielding compressible and flexible material such as felt, cork, rubber, leather or fabric, and is of a width and diameter such that it fits closely within the space between the stationary axlebox cover and the revolving wheel boss 7, in contact with the machined side faces of those parts, the inner periphery being shaped to correspond to the axle contour. The ring is divided so that it may be placed over and around the axle. The outer periphery of the ring is formed with a large deep Vee groove and a coiled spring 10 is laid in this groove its ends being detachably connected, as by hooks, to place the spring under tension. Thus, the inward pressure of the spring on the inclined sides of the groove expands the side portions of the ring 8 outwards and causes them to press firmly upon the opposed lateral faces of the axlebox cover plate 5 and the wheel boss 7. One side of the ring 8 is stepped at 12 to engage over the outer end of the abutment ring 4. The packing ring 8 thus seals the joint between the cover plate 5 and the abutment ring 4, as



well as the joint between the latter and the axle, and, in use, it revolves with the axle, one of its side faces rubbing over the surface of the stationary cover plate 5. The spring 10 maintains a constant expanding action on the ring, thus ensuring a pressure on the engaging surfaces. It also acts to adjust the ring to take up wear. The ring 8 may be faced with thin rings of a harder material to withstand wear or it may be composed of a hard substance such as metal, synthetic resin, wood or vulcanised fibre. In this case, it would be of channel section with thin flexible and elastic walls. (*Accepted January* 24, 1940.)

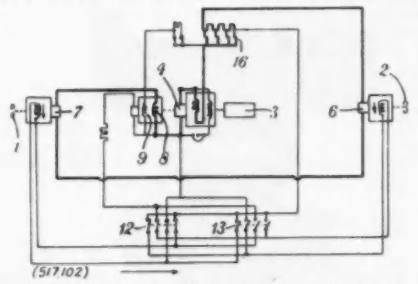
SHIPS AND NAUTICAL APPLIANCES.

516,582. Motor-Boat Propulsion. John I. Thornycroft and Company, Limited, of Westminster, and Sir J. E. Thornycroft, K.B.E., of Westminster. (1 *Fig.*) June 29, 1938.—The invention is a weight-saving arrangement of the engines of motor torpedo boats which enables either the maximum power of the engines to be utilised or one of them to be disconnected from the propeller shaft when running only at cruising speed. *a* and *b* are two aligned engines, the shafts of which extend inwards to an intermediate pinion shaft *c* provided with clutches *d*, between which and the engine shafts are flexible couplings *e*. The short hollow shafts of these couplings are



mounted in bearings in the gearbox and carry the internally-grooved outer casings of the clutches. Inside the casings are grooved clutch plates, which are splined on the shaft *c* and are hydraulically engaged and disengaged with the casings. The shaft *c* carries two pinions *g* and g^1 geared respectively to an ahead gear wheel *h* connected to the propeller shaft through an internal oil-operated clutch and to an intermediate wheel meshing with the astern gear wheel h^2 also connected with the propeller shaft through an internal oil-operated clutch. The engines are arranged to rotate the shaft in the same direction. (*Accepted January* 5, 1940.)

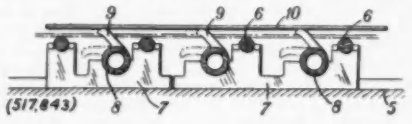
517,102. Electric Ship Propulsion. The British Thomson-Houston Company, Limited, of London, D. E. Jewitt, of Rugby, and R. D. Marsh, of Rugby. (2 *Figs.*) August 31, 1938.—The invention is an electric system of ship propulsion for ferry boats fitted with a propeller at each end. The scheme utilises a constant-voltage generator and two propeller motors with armatures connected in series and with field systems separately excited from the constant-voltage generator. In this way, it is possible to maintain a steadier load on the power system than would otherwise be obtainable when operating shunt-wound motors on a constant-voltage supply under the normally fluctuating load conditions obtaining in a seaway. The vessel is shown being propelled in the direction of the arrow with propeller 1 developing the main thrust load, and propeller 2 merely rotating at zero thrust or, under certain loading conditions, developing a portion of the propelling effort as a tractor screw. 3 is the prime mover, and 4 is the main compound-wound generator. A small booster has its armature connected in series with the field winding of the propeller motor 6, which, in turn, is excited by the main generator 4. The booster is excited in part by a series winding 8, which carries the main power current, and is energised in a direction which tends to increase the voltage of the excitation taken from the main generator 4. The booster is provided with a second field winding 9 which is polarised in a direction opposite to the series field winding 8, and takes its energising current from the main generator 4. The field winding of the propeller motor 7 is energised at full voltage. 12, 13 are four-pole reversing switches which can



only be operated when all the starting switches 16 are open. With the vessel under way in the direction of the arrow and with full load current circulating through the booster field winding 8, the magnetising effect of field winding 9 cancels the effect of field winding 8, and gives zero voltage across the booster armature. Any increase in load on the propeller motor 7, and consequent increase in current through the booster field 8, causes a rapid increase in field strength of the propeller motor 6, this being assisted by the fact that both the booster and propeller motor 6 are normally functioning with low flux values in their field systems. This arrangement automatically causes the forward propeller motor 6 to increase its torque whenever there is a tendency for the main load current to increase above normal value. The propeller loads tend to fluctuate through wide limits if the vessel is subject to any appreciable wave motion and even in smooth water considerable fluctuation of thrust and torque is experienced after reversing the direction of rotation of a propeller in order to stop and reverse the direction of the vessel. (*Accepted January* 19, 1940.)

MISCELLANEOUS.

517,843. Conveyor. Gibbons Brothers, Limited, of Dudley, Baldwins, Limited, of London, and R. Marchant, of Pontypool. (4 *Figs.*) August 10, 1938.—The conveyor is of the step-by-step type and is for conveying bars, billets or plates through a furnace and delivering them to, say, a rolling mill. A track is supported on the floor 5 of the furnace and consists of two pairs of parallel steel skids 6 extending for the length of the furnace. The skids are supported upon stools 7 carried on the floor of the furnace. Between each two adjacent skids is mounted a carrier bar 8 supported on the stools. The bar is reciprocated lengthways of the furnace and has limited rotation. Each of these bars carries a series of snugs 9, which project in a common plane tangential to the surface of the carrier bar. The snugs engage and move the articles to be treated and are suitably shaped to facilitate this



engagement. The figure illustrates the conveyance of plates 10 through the furnace. The carrier bars are interconnected for simultaneous operation and are connected at the delivery end to a wheeled carriage which is moved to and fro to reciprocate the carrier bars. Each carrier bar is coupled to a shaft on the carriage connected at its other end to a helical cam. Brackets on the side of the carriage support rollers engaging with the cam tracks on the shafts coupled to the carrier bars. The initial forward movement of the carriage engages the rollers with the cams and rotates the carrier bars, the snugs lifting the plates clear of the skids. Further forward movement of the carriage reciprocates the carrier bars to advance the plates through the furnace. Lost motion, for allowing the completion of the rotation of the carrier bars prior to the commencement of the advancing movement, is permitted by allowing the shafts coupled to the carrier bars to slide through their bearings on the carriage, the carriage engaging abutments on these shafts at the end of the rotation. The reverse sequence is followed on the return stroke. (*Accepted February* 9, 1940.)